FORESTRY

THE JOURNAL OF THE SOCIETY OF FORESTERS OF GREAT BRITAIN

Edited by R. W. V. PALMER

VOLUME XXXIV : NUMBER 1

Forestry in west central Wales
F. C. BEST and J. R. HAMPSON

Insecticidal control of the Pine Looper in Great Britain
II. *Population assessment and fogging*
D. BEVAN

Some common mosses as indicators in forestry
I. G. HALL

Yorkshire Excursion
Hardwoods

Studies on *Ulmus*, IV. The village elms of Huntingdonshire
R. H. RICHENS

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G. MELVYN HOWE

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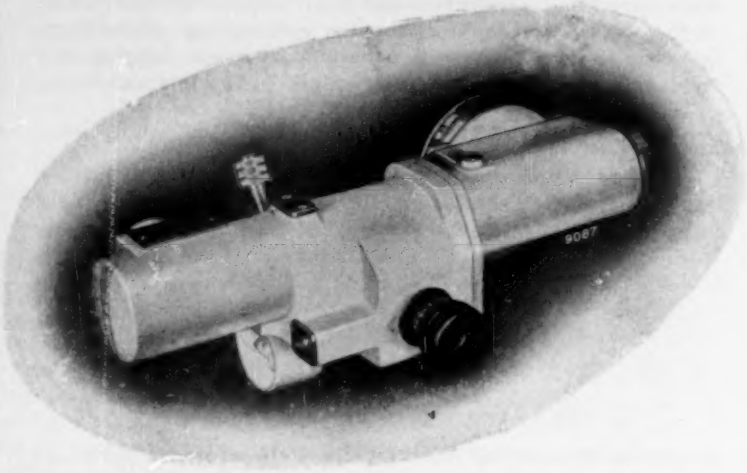

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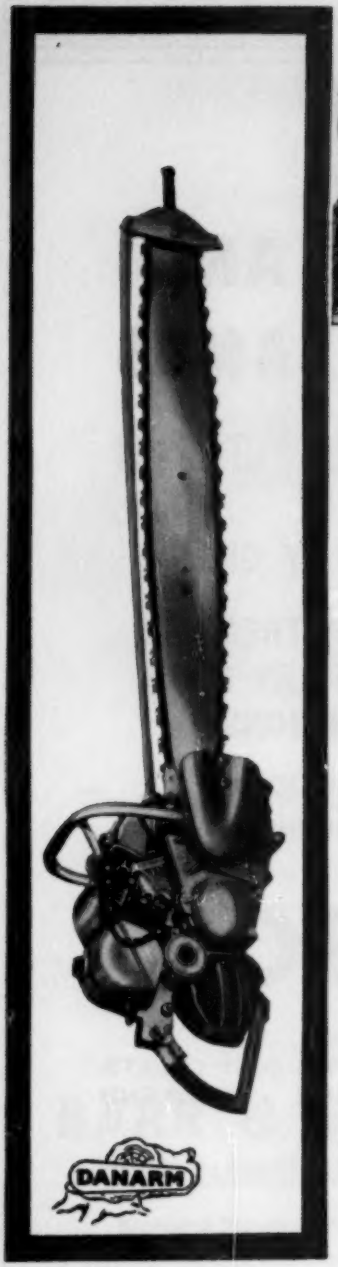

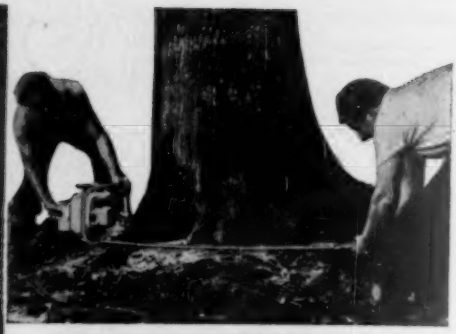

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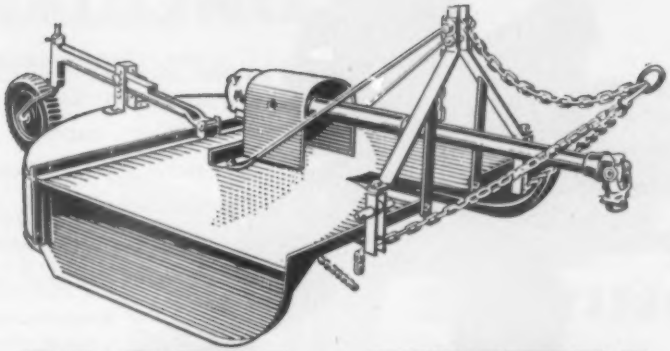

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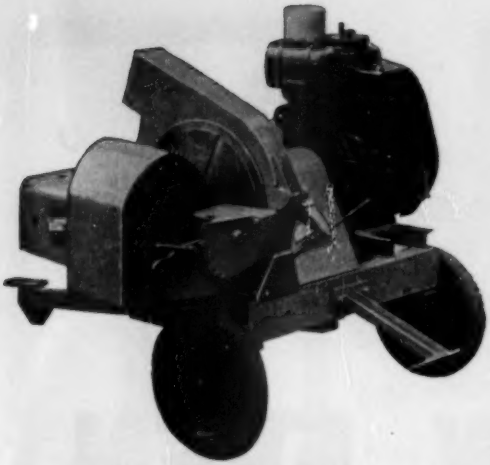

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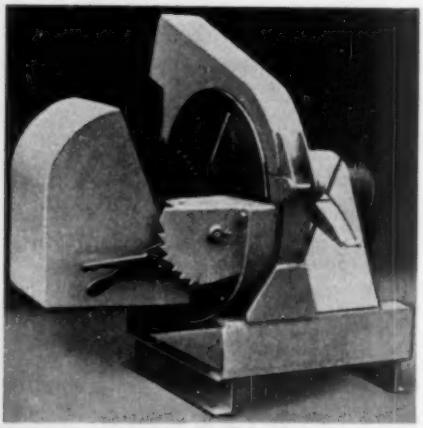

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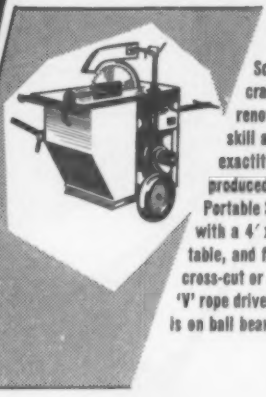

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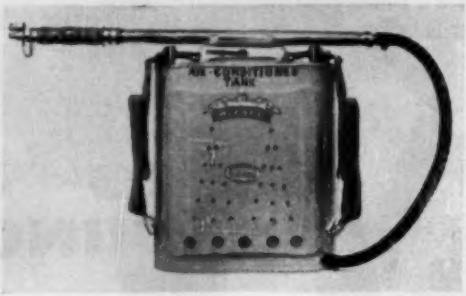

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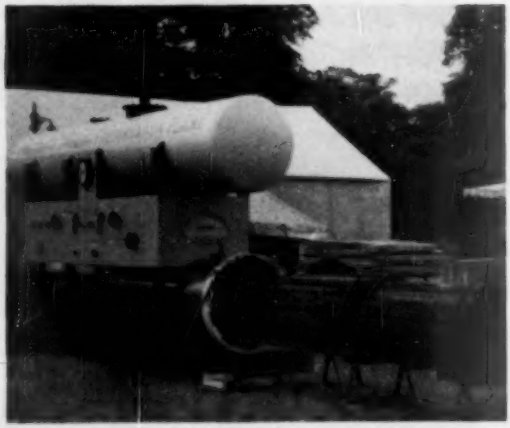

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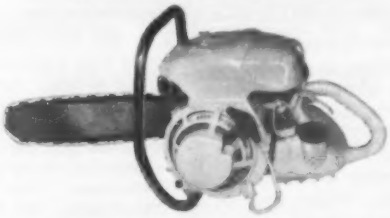

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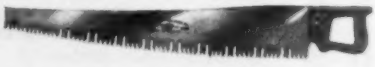

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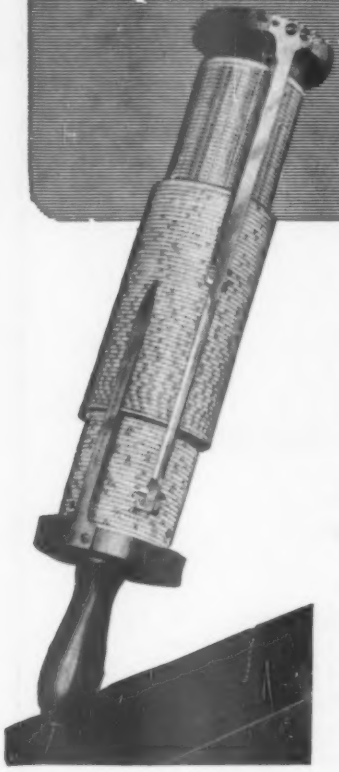

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FIG. 1. Myherin Forest. Old larches, planted *c.* 1795 by Thomas Johnes, pioneer of upland reclamation at Hafod, Cardiganshire. These larches were felled some years ago.

PLATE I

FORESTRY IN WEST CENTRAL WALES

F. C. BEST AND J. R. HAMPSON

(*Forestry Commission*)

(With seven plates)

SUMMARY

The authors write briefly on history, topography, geology, climate, on soils and vegetation, and on protection. Figures are given for Forestry Commission forests and for private woodlands in the area up to the year 1960. Silviculture, growth and yield, production and utilization, and the research programme are each discussed and the probable future for forestry development in the area is outlined. There are eleven photographs and a short selected bibliography.

CENTRAL WALES, of which the area under report forms part, lacks the grandeur of the north and the industrial wealth of the south and is comparatively little known to the general public. It differs markedly in climate and in its silvicultural problems from the east.

1. *History.* In the Middle Ages and until the end of the last century, central Wales enjoyed a prosperity based on lead throughout most of the area and on slate in the extreme north, but now only one slate quarry is worked and all the lead mines are closed.

In those days of rural prosperity the country supported a much higher population; agriculture flourished and homesteads were occupied in the remotest valleys and far up into the hills. Land in the valleys was intensively farmed and the population of cattle in the hill land was much greater than now. The native oak woods, which must have occupied much of the steep hillsides, were burnt for lead smelting and, although the landed proprietors carried out some replanting with conifers, the woodland area gradually dwindled.

At one time large estates occupied much of the countryside. The Llanbrynmair estate of Sir Watkin Williams-Wynn, the Plas Machynlleth estate of the Edwards family, the Gogerddan estate of the ancient family of Pryse, the Crosswood estate of the Vaughans, the Hafod estate made famous by the pioneering work of Thomas Johnes, and the Peniarth estate of the Wynnes occupied much of the country. Some planting was carried out by all these estates and during the present century the Buckleys of Dinas Mawddwy and the Waltons of Cwmllecoe diog settled in the area and carried out considerable afforestation.

Special mention should be made of the Hafod estate, immortalized by Elizabeth Inglis-Jones in her book *Peacocks in Paradise*, and how the then owner Thomas Johnes planted some 1,500 acres 160 years ago. Johnes's plantations were of oak, beech, and larch and extended quite high up in the hills; he was a pioneer of land improvement and although the estate passed from his family on his death in 1824, subsequent owners maintained the woods up to the world wars, the second of which saw their complete destruction.

Such larch as remained until the Second World War was of fine quality and probably of Scottish origin but, with the exception of much reduced areas of Llanbrynmair and Peniarth estates, all these properties have disappeared and little now remains of their plantations and, apart from a few small policy woodlands and oak woods grown mostly from coppice, there is hardly a wood remaining which dates from before 1914.

The Forestry Commission started at Dovey in 1926 and their forests were well established by the Second World War. In fact no new forests have been started since then though extensive additions have been made to existing forests.

Crosswood Park, until recently the home of the Earls of Lisburne, has become the Welsh headquarters of the National Agricultural Advisory Service and such woods as remain there have passed into government ownership.

It has fallen to Dovey Woodlands Co-operative Society with the aid of the Forestry Commission planting grants to make progress in restocking the steep lower slopes of scrub and bracken.

Private forestry also has made advances and the two old estates of Llanbrynmair and Peniarth have dedicated their woodlands. The formation of Dovey Woodlands in 1948 has brought in a new class of woodland owner, the sheep farmer and other owners of small woodlands, so the picture now has changed completely from what it was 50 years ago.

The Hill Farming and Livestock Rearing Acts 1946 to 1956 have supported sheep farming and enabled much land improvement to be undertaken. Only in a few cases have shelterbelts been planted with the aid of hill farming grants, and in far more cases have these schemes enabled felled woodlands to be converted to agricultural use.

Agriculture is again more prosperous and, although remote farms are no longer occupied and many small steep enclosures once under cultivation have reverted to bracken, there is now a larger sheep population in the country than ever before.

The grazing of stock—sheep, goats, and cattle in earlier times—but now largely sheep, has exerted a marked influence on the vegetation of the hill land. The natural oak woods fail to regenerate after felling, heather has largely disappeared except from limited areas of moorland, and gorse (*Ulex galii*) is seldom much in evidence prior to inclosure.

The Aberystwyth area has become the national centre for grassland improvement and the late Sir George Stapleton's work on the Cahn Hill Improvement Scheme and later the Welsh Plant Breeding Station have paved the way to the extensive reseeding of mountain pastures that has taken place during the past 20 years, but the steep bracken slopes, a product of overgrazing by sheep, remain as a challenge to the farmer and a source of hope to the forester.

The Lake Vyrnwy Estate of 22,800 acres acquired by Liverpool Corporation from several owners between 1880 and 1887 and the 1,121 acre reservoir constitutes the principal supply of water to the City of Liverpool. The 4,600 acres of plantations are managed by a unique joint scheme agreed between the Corporation and the Forestry Commissioners. Under this scheme, costs and receipts are shared

equally between the two parties. Timber production in 1960 was 1,135,000 hoppus feet giving receipts of £91,000.

Prior to acquisition some 260 people were supported by the remote upland farms and in the now submerged village. Today more than 500 people are supported by the improved farms, smallholdings, forest and water works and this number is being increased constantly by the employees of timber merchants. The replacement village of Llanwddyn has recently acquired a new school and community centre of advanced design. Tourist traffic has reached embarrassing proportions.

The Dovey is a river of some reputation for sea trout and salmon but most of the North Cardiganshire rivers are polluted with lead and hold few fish.

Overgrazing by sheep has reduced the heather to such an extent that grouse exist as a sporting bird only in a few places.

2. *Topography*. The area with which we are concerned is bounded on the north by the crags of Cader Idris (2,927 ft.); on the south by the valley of the river Ystwyth; on the west by the coastal plateaux and cliffs of Cardigan Bay; on the north-east by Lake Vyrnwy, lying under the highest point of the Berwyn range, Aran Mawddwy (2,970 ft.); and on the south-east by the Elan Valley Reservoirs.

Dominating the centre of the area are the groups of rounded mountains and upland bogs culminating in Plynlimon (2,468 ft.), the source of the rivers Severn and Wye flowing east and south into England and of the Rheidol flowing westward to Aberystwyth.

Such short westward flowing rivers, with their steep-sided valleys cut among the rounded hills and plateau bogs, are characteristic features of the area. The principal one is the river Dovey which rises under Aran Mawddwy, the highest hill in Wales outside Snowdonia, and forms a clear boundary between the thriving plantations and bracken slopes of Dovey Forest to the north and the difficult forest conditions found to the south. Here the Plynlimon group of forests forms the northern outlier of the great 'Welsh Desert' of the Cambrian Range—a land of high rainfall, poor drainage, eroded soils, and extreme exposure from the prevailing maritime winds. But this kind of country is of great importance to foresters in Britain, for it is to these difficult uplands that their attention must be turned if the Government's statement on forestry policy of July 1958 is to be put into effect.

Upland lakes abound, and are mostly artificial or were increased in size by man to provide power and washing water for the innumerable lead mines of the south and for the slate mines and quarries of the north. A characteristic feature of the area is the carefully constructed open leats which carried the water contourwise from the lakes to the crushing- and washing-mills—often several miles away. Now, the mines and quarries are silent and the leats overgrown, but the lakes are valued as domestic water supplies and provide good fishing. More recently the waters are being harnessed for the Rheidol Hydro-Electricity Scheme whose three lakes and dams with associated transmission lines and tunnels are becoming as prominent, locally, as the forest plantations and roads set among the closely grazed mountain sheep pastures.

This then is the pattern today which man has drawn on the natural features of the area. For a long time in the future it is likely that hill-sheep farming, forestry, and water-supply, together with the tourist traffic which the latter will increase, will govern the general development and appearance of the region.

3. *Geology*. The mid-Wales forest region lies near the heart of an area where early geological investigations proved of fundamental importance and it has been said that no area of its size throughout the world has had such an influence upon the advancement of the science. The rocks belong to the Lower Palaeozoic era and the succession of sedimentary rocks carry Welsh names which have been given to rocks of the same age and characteristics wherever they are found throughout the world.

The succession of the rocks in the area is as follows:

Era	*Systems*	*Series*
Lower Palaeozoic	Silurian	Wenlock
		Llandoverian
	Ordovician	Bala
		Llandeilo
		Llanvirn
		Arenig

These are separated from the Cambrian rocks to the north by the intruding and durable igneous rocks of Cader Idris, which adjoins the northern boundary of Dovey Forest.

The northern slopes of the Dovey valley form a major division between the Ordovician system northwards and the Silurian to the south—where only the rounded tops of the Plynlimon area stand out as Ordovician 'islands'.

Broadly speaking it may be said that forest plantations thrive on the Ordovician (Bala) and Silurian (Llandoverian) slates and shales north of the Dovey valley, and are typically associated with slate mining and quarrying areas.

South of the Dovey valley, forest plantations need much greater care and attention to detail if success is to be obtained on the Silurian (Llandoverian) shales, though much of the difficulty is probably caused by erosion of derived material on the steep slopes, with impervious glacial clay damming-up and underlying the more level ground. Associated with this difficult forest country are the lode faults containing large quantities of galena and zinc blende. Where mined there is local poisoning of vegetation by spoil and a general dearth of fish and other aquatic life in the rivers; but so far there is no evidence that the presence of lodes is in any way responsible for the poor tree growth compared to the slate areas of the north.

In the area of Aberystwyth Grits to the south-west, along the coast of Cardigan Bay, there is evidence of uplift in the coastal plateaux and of subsidence in recent geological times as demonstrated remarkably in the 'submerged forest' of Borth Bog at the mouth of the Dovey where the remains of Scots pine and birch may still be seen at low tides.

FIG. 2. Myherin Forest. Remnants of the planting of Thomas Johnes of Hafod now interplanted

FIG. 3. Dovey Forest. Plantations on ending slopes and screes

PLATE II

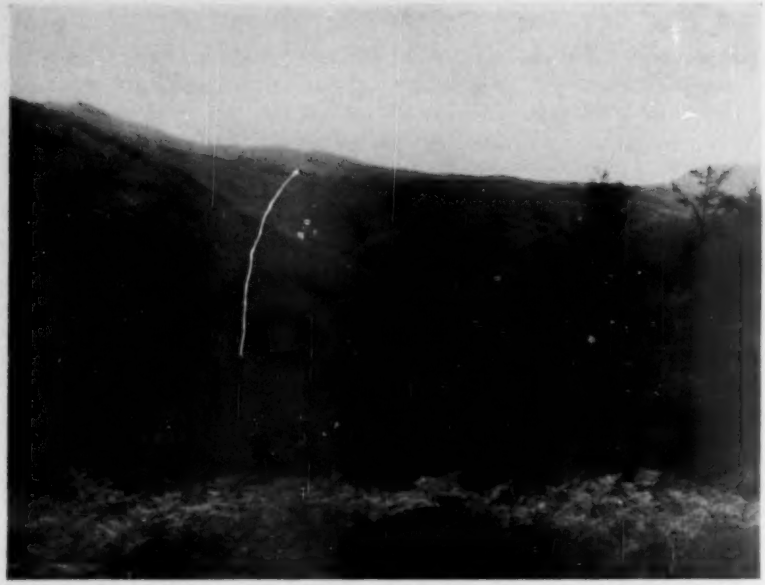

FIG. 4. Dovey Forest. Cwm-Caws, the 'Cheese' valley at Dovey Forest. Forestry Commission plantations following larch plantations of the Cwmllecoediog estate. The name indicates the earlier prevalance of cattle in a present-day sheep locality

FIG. 5. Dovey Forest. Douglas fir and *Tsuga heterophylla* replaces girdled scrub oak in the steep valleys

PLATE III

FIG. 6. Dovey Forest. Twenty-one-year-old *Tsuga heterophylla* planted under old European larch

PLATE IV

FIG. 7. Dovey Forest. Fourteen-year-old *Nothofagus procera* with Japanese larch of same age in background

PLATE V

FIG. 8. Dovey Forest. Plantations and small holdings

FIG. 9. Myherin Forest. General view of typical plantations in the difficult 'Plynlimon' country, with National Agricultural Advisory Service Pwllpeiran Experimental Husbandry Farm land adjoining

PLATE VI

FIG. 10. Tarenig Forest. Nant Rhys upland bog typical of the 'Welsh Desert' showing combinations of Cuthbertson ploughing prior to planting

FIG. 11. Lake Vyrnwy. Plantations of the joint Liverpool Corporation and Forestry Commission Scheme

PLATE VII

4. *Climate.* The forest land lies mainly on the steep valley slopes and uplands, and exposure to the prevailing south-west winds, still fresh from the sea, is a major feature of the area.

Rainfall is generally very heavy, averaging about 100 inches a year in the shadow of the highest ground but dropping to 35 inches a year along the coastal belt.

It is a feature of the area that the lowest rainfall period of the year coincides with the start of the growing season, and this can lead to great difficulty in getting plantations to grow vigorously on the steepest freely drained slopes, south of the Dovey valley.

Late frosts have caused severe damage in the past, particularly in 1935, but the area has been relatively free of this damage over the past 10 years.

Snow falls can be heavy on the eastern side of the highest mountains but do not lie for long to the west.

Freak weather conditions are not unusual, and have included a whirlwind which uprooted pole-size trees (Tarenig Forest 1947), 7 inches of rain in 5 hours (Tarenig 1949), landslides (Tarenig 1958), and most memorable of all, the ice-storm of January 1940 which created havoc from the centre of the area eastwards.

5. *Soils and vegetation.* North of the river Dovey, the forest soils on the steep slopes are typically shaley loams of good depth, and have usually carried heavy bracken or scrub woodland. There are no extensive moorlands and the little visible rock lies in upright laminae which encourage good drainage, deep rooting, and a degree of resistance to erosion of top soil.

South of the Dovey, the forest land divides into:

(*a*) Steep valley sides of a light shaley loam, which usually carry a dense but poor vegetation of nardus grass, bilberry (*Vaccinium*), heather, and dwarf gorse (*Ulex galii*). De-forestation and very intensive sheep-grazing in the past, coupled with a heavy rainfall, have probably led to a severe erosion of the top soil, and what remains as a rooting medium may be the typically rufous 'B-horizon' of a truncated podsol.

(*b*) Rolling uplands of peat lying over impervious glacial clay and carrying a typical moorland vegetation of *Molinia* deteriorating to *Scirpus*, cross-leaved heath (*Erica tetralix*), sphagnum, and cotton grass (*Eriophorum vaginatum*) as the stagnation and acidity increase. There is evidence in remains of large oak, birch, and mountain ash that much of the highest land was forested in ancient times.

It will not be out of place to mention here the principles underlying soil survey and description as devised by G. W. Robinson and his staff at the University College of North Wales (Bangor) in the 1930's. It is, of course, the soil profile which concerns the forester most and 'the underlying consideration is that the character of the soil is determined by the nature of the parent material and also by the conditions of formation. According to the classification now adopted, soils are grouped into series, each series consisting of a group of soils derived from the same or similar parent material under the same conditions of formation and showing a general similarity of profile in vertical section.' Hence arises the classified series of soil profiles, whose Welsh place-names are now in common use among soil scientists.

6. *Protection.* Apart from extensive *Molinia* areas in the Plynlimon country where the danger from fire is considerable in early spring, there are no extensive areas of gorse and heather so common elsewhere in Wales and generally speaking the danger from fire is not great. Overgrazing and overburning in the past have largely eliminated the most dangerous types of vegetation and in addition the area lacks the high tourist attraction of the north or the industrial population of the south. Among living organisms the ever-present sheep has caused more expense, if not more damage, than anything else so far. As a protection against *Fomes*, stump creosoting after thinning is standard practice.

TABLE I. *Forestry Commission Forests West Central Wales, October 1960*

Forest	*Area planted (acres)*	*Area remaining to be planted (acres)*	*F.C. farms and holdings*		*No. of forest workers*		*Total roads constructed (miles)*
			(No.)	*(Acres)*	*F.C.*	*Contractors*	
Dovey . .	15,732	1,084	37	1,351	174	26	104
Taliesin . .	2,676	2,257	2	1,850	24	..	7
Rheidol . .	2,838	1,039	3	596	18	..	4
Ystwyth .	4,352	130	12	335	74	18	26
Myherin .	3,533	92	5	184	18	..	16
Tarenig . .	2,917	248	3	195	18	3	16
Hafren . .	8,470	173	4	1,048	43	..	32
Total . .	40,518	5,023	66	5,559	369	47	205

7. *Forestry Commission forests.* Dovey Forest, started in 1926, is now the largest forest in North Wales and, due to the generally good quality of the land although not the oldest forest, it is now producing the largest volume of timber. The Dovey valley is a region of good agricultural land in the main river valley but the uplands consist of steep sided sheltered valleys running down from the higher hills of the water sheds. This is ideal forest country where a wide choice of species can be planted.

Roads were almost non-existent and a large programme has been necessary to keep pace with production.

A considerable proportion of all forests, particularly of post-war acquisition, has consisted of small woodland areas on steep hillsides at lower elevations. These are generally excellent sites and a wide range of species is grown, but costs are high.

The forests of the Plynlimon country are largely on grass land subject to severe exposure. These are essentially Sitka spruce (*Picea sitchensis*) forests with Japanese larch (*Larix leptolepis*) as a pioneer crop on some of the difficult dry slopes.

The story of planting methods is similar to that of so many hill forests. Turf planting was first practiced on wet peat areas and gradually extended to other peaty soils, but the advent of ploughing has almost limited turf planting to a filling in operation for the odd corners and the steepest slopes that cannot be ploughed.

Phosphate as basic slag was tried occasionally in the early years but without

much success; on the more difficult sites now being planted the application of concentrated phosphate is a regular practice.

8. *Private forestry.* It is difficult to know the extent of early planting of oak as most of the remaining oak woods on steep hillsides are of native sessile oak (*Quercus petraea*). Pedunculate oak (*Q. robur*) exists often as park trees, and trees of intermediate character are now common, but whether these are hybrids or variants of sessile stock is a matter of controversy.

Besides oak, European larch and beech were planted on some scale for timber production last century. Norway spruce, Scots pine, and Silver fir were also used but more often in policy woodlands and the remaining old Scots pine have done remarkably well compared with more recent plantings.

Douglas fir (*Pseudotsuga taxifolia*) was occasionally planted up to the First World War but thereafter Japanese larch came into favour owing to its satisfactory early growth.

The post-war development of private forestry is largely associated with the setting up of Dovey Woodlands—*Coedlannau bro Ddyfi*—in 1948. This is a private co-operative woodland society run by woodland owners in South Merionethshire, West Montgomeryshire, and North Cardiganshire. During the thirteen years of its existence it has planted 1,244 acres and it now has 220 members with a total woodland area of 4,500 acres. The majority of members are sheep farmers but the estates in the area, with one exception all small, are almost all members. The Society is divided into three groups, each under the control of a trained foreman and the whole under the control of a manager who is a trained forester. There is a small timber yard largely for use during bad weather. Men are employed and the Society is administered by a committee and a secretary.

There is a gradually growing appreciation among farmers of the value to them of woodland for the production of timber for use on the farms and as an investment, but this is an entirely new outlook because there has been no forest tradition among sheep farmers in the past. The favourable conditions for tree growth have attracted a few non-residents to invest money in forestry on a moderate scale.

The Welsh Woodland Survey was started in 1950 with the object of gaining factual information about the existing stocking and adequacy of management of every wood in Wales and with the intention of advising the owners of such woods as were suitable for economic management and persuading them, where the state of the wood warranted it, to take action to bring it into full production. Several visits were usually made by District Officers in an effort to persuade each owner to adopt a positive policy of woodland management at reasonable speed. If successful, the work is done either by the owner, co-operative society or contractor. As a last resort, or where pressed by the owner, the Forestry Commission sometimes does the work on an agency basis. If unsuccessful in persuading the owner to act himself, the area may be bought or leased by the Forestry Commission. The Woodland Surveys in North Wales Conservancy were completed in 1960 and, in the area being described, the private woodland contribution is summarized below.

From this it will be seen that the area is one of small woodland ownerships, typical of much of Wales, where painstaking and detailed work is necessary to

preserve and increase the proportion of well managed woodlands. Though size, shape, access, and other important site characteristics are sometimes poor these disadvantages are often outweighed by the highly productive soil and favourable climate of the private woodland situations.

Total land area	435,300 acres
Percentage woodland of total land area	3·3 per cent.
Total number of woodland owners	511
Total acreage of private woodlands	14,318 acres
Average acreage of woodland per owner	28 acres
Total acreage of dedicated and approved woods	2,328 acres
Total number of owners of dedicated and approved woods	13
Average acreage of dedicated and approved woods	179 acres
Other woods under some other form of management	5,040 acres
Number of owners of woods under some other form of management	325
Average acreage of woods under some other form of management	15 acres
Percentage managed of total woodland area	51 per cent.
Percentage stocked of total woodland area	40 per cent.

9. *Silviculture.* Although good crops of European larch (*Larix decidua*) were raised in the earlier private plantations it was soon found that Forestry Commission plantations were not thriving and fortunately the species was given up in favour of Japanese larch which was much used, and when planted on the better bracken slopes gave excellent results, quality class I being not unusual. More recently, however, the fall off in the demand for larch timber and the increasing demand for spruce together with the lower increment of larch have given a bias against it except as a pioneer on grass-bilberry sites when other species are difficult to establish. Japanese larch remains a useful pioneer species on some of the more difficult upper slopes where Sitka spruce checks and also for amenity and protection against fire. The replacement of larch crops with plantations of more valuable species affords an interesting problem capable of solution in various ways.

Until 1929 the true value of Sitka spruce was not appreciated and it was the practice to plant Norway spruce (*Picea abies*) on the high ground and to reserve Sitka spruce for the low lying wet or moist areas. The reversal of this practice in 1930 has been fully justified. On all exposed sites Sitka spruce is the outstanding tree.

The central uplands of Wales from Plynlimon south into the upper Towy valley have proved unexpectedly difficult. Soils often appear favourable, and no marked mineral deficiency or toxicity has been detected, yet growth of Sitka spruce has often been very disappointing. Improved establishment methods such as ploughing and application of phosphate have helped, but have not entirely overcome the difficulty and it may be that water deficiency due to frequent spring drought and acute competition from grass combined with severe exposure on trees accustomed, even on the Pacific coast, to rather more continental conditions has something to do with these difficulties.

Dwarf gorse (*Ulex galii*) is sometimes dominant on dry slopes after inclosure. Where the ground is very dry, and the gorse associated with heather, coastal *Pinus contorta* may be the only tree to grow but usually the gorse is pure or

associated with grass when Sitka spruce can generally be grown if pit planted and phosphated, but Lawson cypress (*Chamaecyparis lawsoniana*) has proved a useful species where exposure is not severe.

Climatically the area is suitable for the growth of West American conifers from the Pacific coastal areas, and in the sheltered valleys and deep soils of the Dovey valley *Tsuga heterophylla*, *Abies grandis*, *Thuja plicata*, and *A. procera* do extremely well. It was a pity that in the early years of Forestry Commission planting it was very hard to get anything but the common species and it was only from the very occasional plots of such species as *Tsuga*, *Abies grandis* and *A. procera*, *Thuja*, and Lawson cypress that their silvicultural worth was found out.

The use of *Tsuga* and *A. grandis* has increased in recent years and both species take a prominent part in the replacement of early Japanese larch.

Thuja plicata has proved a fine tree on relatively good sites but its extreme susceptability to *Keithia thujina* has made it an uneconomic tree to plant and very little has been grown.

Abies procera shows some promise on typical Sitka ground and is an extremely hardy and tolerant tree but its liability to stem crack makes its future uncertain unless it is acceptable for pulp. It has not been used extensively as, although good home seed can be collected every few years, its true value as a timber producer has still to be proved.

Douglas fir (*Pseudotsuga taxifolia*) was used extensively in the early years for planting the lower bracken slopes but gave much trouble from wind rock when young. The climate may be a little too oceanic for it but so long as a low elevation coastal strain is used and it is planted on firm well-drained sheltered ground, preferably with a south aspect, it can do very well.

With the occasional exception of *Pinus contorta*, the pines have a place only on very dry sites at low elevation. *P. contorta* of true coastal strain is a valuable tree on dry sites or on very tight peat but it will not stand up to the same degree of exposure as Sitka spruce. Although some fine old Scots pine (*P. sylvestris*) have been grown in the valleys it is now confined to the thinnest or dryest of soils at low elevation that will not support one of the higher volume producing conifers such as Douglas fir. It has proved intolerant of climatic conditions at high elevation and its recent use as a nurse to Sitka spruce on heather ground has been restricted to rocky sites at low elevation.

Corsican pine (*P. nigra* var. *calabrica*) is liable to die-back and to be attacked by *Brunchorstia* and, owing to the terrible reputation earned at Lake Vyrnwy, was a forbidden species. Recent acquisition of land near the sea has, however, provided a place for it on dry exposed sites at low elevation.

A group of *Pinus peuce*, 31 years of age, at Ystwyth gave encouragement to try it out elsewhere in North Wales.

Close to the coast, rainfall is low and climate mild and *Pinus radiata* may just have a place.

Unfortunately the *Sequoias*, *Cryptomeria*, and *Picea omorika* have not been tried out long enough to know whether they have any place in the silviculture of the area.

With the possible exception of *Nothofagus procera*, the scope for growing

hardwoods is extremely limited but part of Dovey is in the Snowdonia National Park and most of the rest of the area is in one or other of the areas of Special Scenic Beauty so a little hardwood needs to be grown on lower slopes to give variety and meet the demands of contemporary tastes in amenity. One pre-war plot of *Nothofagus procera* at Dovey is outstanding and at 24 years of age it has more than held its own with Japanese larch in moderate exposure. Post-war plantings are as yet young but encouraging, and it is interesting to note its freedom from frosting, whereas *N. obliqua* has not proved entirely hardy.

The much milder climate near the sea has enabled such species as *Eucalyptus urnigera* and *E. johnsoni* to succeed.

10. *Growth and yield.* On the lower valley slopes growth is excellent, Japanese larch and Norway spruce reaching quality class I and super I. In respect of species for which yield tables are not available, the extracts given from sample plot figures in Table II indicate the production of the area.

11. *Production and utilization.* As will have been seen from sections 1 and 8 above the private woodlands are mainly very young and the average size of wood under management (other than dedicated or approved) is only 15 acres. This means production for local use as farm timber but there should be a possibility of entering the more distant markets being developed by the steadily increasing production from Forestry Commission forests, provided that collective marketing arrangements can be made.

With a total today of some 50,000 acres of managed woodland in the region (12 per cent. of the land area) there are prospects for local wood-using industries but at present the main markets are the coal fields of South Wales, North Wales, and the Midlands, and the pulp mill at Ellesmere port on the Mersey. Other important markets include insulation board, wood-wool, saw timber, and fencing. Firewood is in small demand locally but Christmas trees are exported in quantities to England and there is a keen demand for moss-collecting rights and evergreen foliage for wreath-making.

In Forestry Commission areas thinnings are carried out on a 3- or 6-year cycle and for economic reasons the minimum volume which may be removed at each thinning is generally 300 hoppus feet per acre measured by the tariff system. In practice the triennial thinning yield per acre realized averages 400 hoppus feet, or nearly half of the increment. Yield regulation is mainly by area, in working blocks and by individual forests, at this formative stage of development. Work study has shown that the profit from thinning is greatly reduced when thinnings, converted to pit props, pulpwood, &c., are small. It is therefore the practice, particularly in spruce areas, to delay first thinning a little later than the silvicultural optimum and to adopt a system of crown thinning in the early years.

Japanese larch crops of first and second quality class are being heavily thinned and underplanted at about 30 years of age with high volume producing shade bearers. Lower quality larch crops are generally looked on as pioneer crops for early replacement usually by clear felling followed by replanting.

In recent years the proportion of production sold standing to merchants has been steady at about 65 per cent. The 35 per cent. worked by Forestry Commission

TABLE II. *Sample plot figures for species for which yield tables are not available*

Species (not in yield tables)	*Age of crop (yrs.)*	*Main crop*							*Int. yield from thinning*	*Total crop yield to date*	*Annual increment vol. (over bark) q.g.*	
			Height		*True girth at 4 ft. 3 in.*							
		Number of trees per acre after thinning	*Average of 100 largest trees (ft.)*	*Average of crop (ft.)*	*Average of 100 largest trees (in.)*	*Average of crop (in.)*	*Basal area per acre after thinning q.g. (sq. ft.)*	*Vol. per acre (over bark) q.g. (b. ft.)*	*Vol. per acre (over bark) q.g. (b. ft.)*	*Vol. (over bark) q.g. (b. ft.)*	*Current (b. ft.)*	*Mean (b. ft.)*
Thuya plicata	28	918	54½	45½	34	20½	169·0	3,260	1,289	5,790	342	207
Tsuga heterophylla	30	311	71	64½	36½	30½	126·0	3,881	not accurately recorded			
Abies grandis	30	305	72	64½	34½	28	103·3	2,957	..	..	..	..
European larch	55	61	..	67½	..	42	46·3	1,310	1,388	2,698	50	49
underplanted Tsuga heterophylla	25	356	57½	51½	26	20	62·1	1,440	939	2,379	176	97
Abies procera	31	690	49	37½	31	20½	126·4	2,623	1,155	3,778	..	122

staff is confined almost entirely to pulpwood and gives a net return about equal to the standing sales. Merchants seeking security of supplies for a steady labour and supervisory force are finding that about 60,000 hoppus feet per year is needed at each forest for each gang of about four men employed.

12. *Research.* Until the war no special problems had arisen and it seemed that the good results at Dovey might be repeated in the Plynlimon country, but by the end of the war it was apparent that the spruce plantations were not developing as they should on the grass-vaccinium slopes, and many species had taken a severe knock in the winter of 1947, so at the request of the Conservancy the Forestry Commission Research Branch set about investigating the problems of checked plantations and of preventing check in new plantations.

Experiments have been laid down to test species and races, planting and ploughing methods, herbicides, and the making good of mineral and water deficiencies, but while progress has been made it cannot be said that the problem has yet been fully solved.

Locally the spread of Rhododendron is causing a problem to which an economic solution has yet to be found. Clearing and burning, and planting with *Tsuga*, *Abies grandis*, or coastal Douglas fir has proved effective but expensive.

13. *The future.* Since the decline of the slate quarrying and lead mining industries, central Wales has become largely dependent on sheep farming but, in spite of agricultural subsidies and modern methods of grassland improvement, the economic position of the hill sheep farm is precarious and many of the remote farms are becoming uninhabited and many more are being farmed uneconomically by their owners who are loath to give up their ancestral homes and traditional occupation. The stock of sheep in Wales is greater now than ever before but employment in agriculture is falling yearly.

In 1955 the mid-Wales Investigation Report was published and in 1957 the Report by the Natural Resources (Technical) Committee on Forestry, Agriculture and Marginal Land. Both reports recommended a considerable extension of forestry and closer integration between forestry and agriculture on marginal land.

The Pwllpeiran Experimental Husbandry Farm managed by the National Agricultural Advisory Service consists of unplantable hill top and enclosed farm land in the valley below, together with a limited amount of plantable land. The farm lies within the forests of Ystwyth, Myherin, and Tarenig, and one of its purposes is to find out how to integrate forestry and agriculture in the uplands.

The extreme north of the area falls within the Snowdonia National Park and most of the rest of the area is proposed as an Area of Outstanding Natural Beauty. A Forestry Consultative Panel consisting of members of the Park Planning Committees of the three counties concerned and representatives of the Joint Advisory Committee to the Snowdonia National Park, the National Parks Commission, the Council for the Preservation for Rural Wales, the Nature Conservancy, and the Forestry Commission has been set up to settle problems arising out of afforestation in the National Park.

The Nature Conservancy interests are not extensive and consist of the mountain

reserve of Cader Idris, the woodland reserve of Coed Rheidol and the bog reserve of Cors Tregaron and several Areas of Special Scientific Interest.

These considerations are not likely greatly to effect the future development of the area and taking all things into account it seems likely that the present tendency for the remote farms to become unoccupied and for the smaller ones to cease to exist as separate entities will continue and that much more land will in the course of time become available to forestry. The growing demand for spruce for pulp and the accessibility of central Wales to Merseyside and the industrial Midlands suggest great development of Sitka spruce forest on the plateau land with more varied conifer forest in the sheltered valleys.

The extensive hydro-electric development now taking place in the Rheidol valley and the accessibility of mid-Wales is likely to lead to the opening up of this country to tourists but this should be quite in keeping with its further development for forestry.

ACKNOWLEDGEMENTS

The following are thanked for permission to use photographs. *The Guardian* for Fig. 3; Cyril Lindley for Fig. 5; Derek C. Smith for Fig. 9; Powell Duffyn for Fig. 11; and the Forestry Commissioners for the remainder.

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INSECTICIDAL CONTROL OF THE PINE LOOPER IN GREAT BRITAIN

II. *Population assessment and fogging*

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SUMMARY

An attack by *Bupalus piniarius* L., the Pine looper, at Cannock Chase in 1953 (*Forestry*, xxxii. 166) led to an annual routine survey of pupal populations by the Forestry Commission. This survey revealed a gradual rise to epidemic levels at Tentsmuir by 1957 and to control by fogging. The paper describes the precautions taken before control to make sure that losses occurring between pupal and larval stage had not removed the threat. These precautions included sampling on a sufficient scale but the author shows how this last minute sampling could be much reduced by the assumption of a pupal count/egg density relationship. He describes the fogging technique and the climatic conditions needed for success and gives results in larval drop counts.

INTRODUCTION

IN the year 1953 the Pine looper, an indigenous insect, made its first appearance as a forest pest in Great Britain. Crooke (1959) has described how, in that year, the species caused complete defoliation in parts of Cannock Chase Forest, and how, as a result, a survey of population was carried out in this and other woodlands. A similar survey was afterwards instituted as an annual routine protective measure, covering all sizable pine woods throughout the country. The first fruit of this labour was the early warning given of rising population at Tentsmuir in 1956. This was confirmed in 1957 and further investigation became necessary.

The paper records the steps taken which led to control and gives a short account of the control technique and the results obtained.

II. TENTSMUIR FOREST

The forest lies between the rivers Tay and Eden in the county of Fife. The greater part of the planting was carried out in the period 1922–33, Scots and Corsican pines (*Pinus sylvestris* and *P. nigra* var. *calabrica*) being the main species used.

Conditions of site and crop are very close to those found at Culbin, Moray, where a similar first attack of pine looper occurred in 1954 (Crooke, 1959). These forests are the only two in East Scotland, a district with a long history of natural and plantation pine, where this insect has proved to be of economic importance. The factors common to both are therefore of interest. Geographically they are near the extreme northerly limit of the insect's distribution as a recorded pest, sharing about the same latitude as the three infestations reported by Trägårdh (1919) in Sweden. Both are in 'rain-shadows', with rainfalls in the region of

25 inches, and both have relatively high summer temperatures for their locality. The two soils are coastal sands; low-lying flats with a seaward border of unstable dunes at Tentsmuir; high unstable dunes interspersed with pebble beds for the most part at Culbin. In such sites water deficiency and low fertility might be suspected to account for the rather poor quality of the growing stock. Although Ovington (1951) has shown that a water shortage is characteristic of the Culbin crop, he found that Tentsmuir had a high water table and a plentiful supply of moisture. No comparative study of nutrient status exists between these two places though Ovington (1951) states that Tentsmuir is superior to Culbin. This is not reflected, however, in differences of quality class. Wright (1956 and 1957), summarizing the responses of Corsican pine at Culbin to fertilizer applications, shows clearly that nitrogen is in short supply, and it seems more than likely that this deficiency is common to both areas. Exposure is not generally extreme at either forest, nor does there seem to be any other physical factor particularly unfavourable to tree growth. Root rot by *Fomes annosus* has been serious at Tentsmuir but there is no evidence to suggest that this has predisposed *Bupalus* attack.

III. PRELUDE AND OUTBREAK

The numbers of pupae found during the annual surveys indicated that low mean counts of a typical endemic order were present at Tentsmuir both in 1954 (not shown in table) and 1955. The first signs of an increase appeared in 1956, and by 1957 a potentially damaging population appeared (see Table I). The 26 compartments sampled in 1955, distributed throughout the forest in the usual manner (Forestry Commission, 1959), produced a range of counts between 0 and 1 pupa per sq. yd. In 1956, 24 compartments were sampled and the range this time was between 0 and 7·6 pupae per sq. yd. The 1957 survey covered the compartments sampled in 1956, and a further 27 were added as a result of the high numbers found during the first visit; counts ranging from 0 to 72 pupae per sq. yd. were recorded as can be seen from the following summary and from Fig. 1.

Mean pupal count	*Number of compartments*
70–80	1
50–60	1
40–50	5
30–40	3
20–30	10
10–20	17
Less than 10	24

IV. CONSIDERATION OF THE SITUATION IN SPRING 1957

Pupal counts give warning of attack but losses occurring between the pupal stage and the damaging larval stages may be sufficient to reduce the population to harmless levels. Hitherto foresters have had to plan control mainly on pupal counts tempered by experience. Schwerdtfeger (1941), for instance, gives a figure

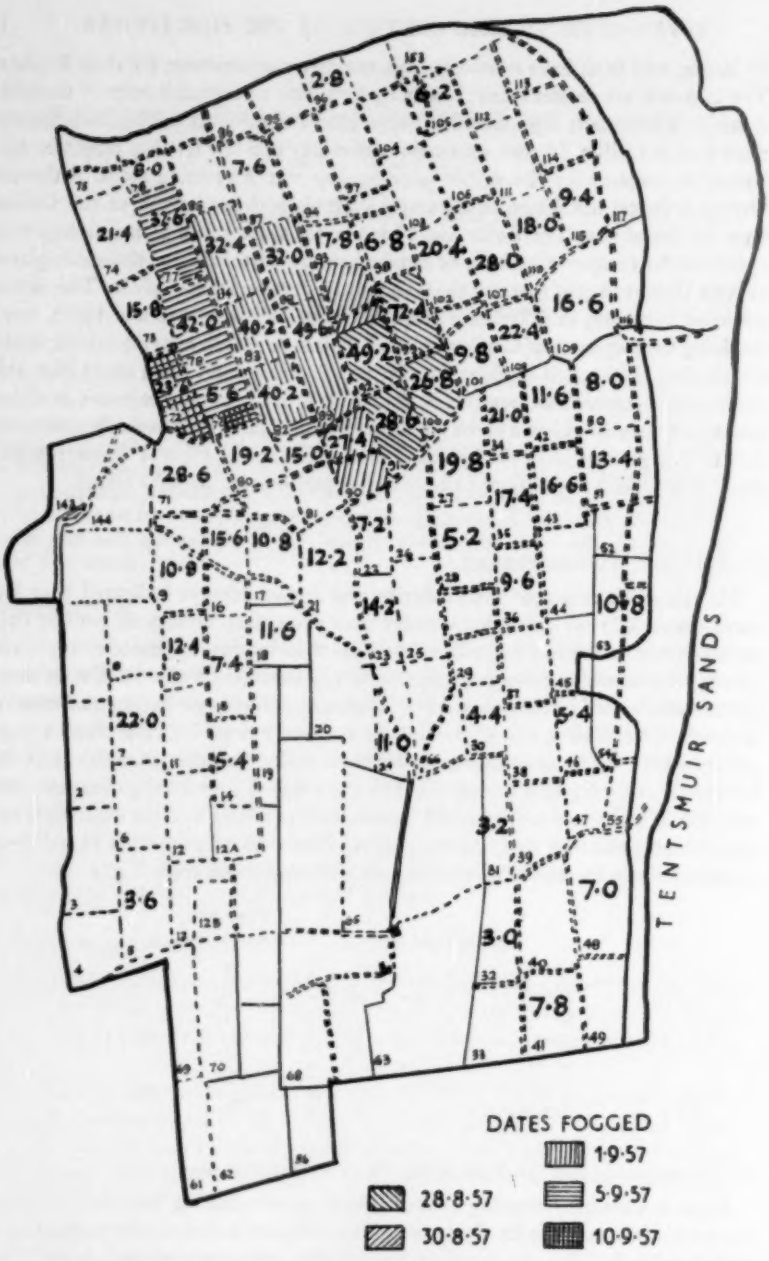

FIG. 1. Tentsmuir Forest. Pupal counts and control area. Bold figures are the number of pupae per square yard. Small figures are compartment numbers.

of 6 pupae per sq. m. as indicating the threat of 50 per cent. defoliation, and suggests that this should be taken as a critical figure. In this country such numbers are frequently exceeded by a wide margin without resulting defoliation. Further, our brief experience with this insect confirms that the later stage population actually realized from any pupal density is a very variable quantity, and that, therefore, pupal counts can only provide a warning. The fate of a population is still in the balance until the actual damaging stage has been reached.

TABLE I. *Mean pupae count in pupae per sq. yd. by compartments*

Cpts.	*Spring 1955*	*Spring 1956*	*Spring 1957*	*Spring 1958*	*Cpts.*	*Spring 1955*	*Spring 1956*	*Spring 1957*	*Spring 1958*
5	..	4·8	3·6	0·6	**72**	..	..	**23·6**	..
7	..	7·6	22·0	1·2	73	..	..	15·8	0·0
9	..	..	10·8	0·4	74	..	4·0	21·4	0·8
10	..	..	12·4	..	**77**	**0·2**	..	**32·6**	**0·0**
14	..	..	5·4	0·4	**78**	..	..	**42·0**	..
15	..	..	7·4	1·2	**79**	**0·4**	..	**5·6**	**0·0**
16	0·8	..	15·6	0·6	80	..	..	19·2	..
17	..	..	10·8	0·6	81	..	1·0	15·0	0·0
18	..	3·4	11·6	..	**82**	..	..	**40·2**	..
21	..	..	12·2	..	**83**	..	**5·2**	**40·2**	..
22	..	..	7·2	1·4	**84**	..	..	**32·4**	..
23	..	5·4	14·2	..	87	..	..	7·6	..
24	..	..	11·0	..	**88**	..	..	**32·0**	**0·0**
26	..	..	7·8	0·6	**89**	**0·8**	..	**49·6**	**0·2**
27	..	..	19·8	..	**90**	..	..	**27·4**	..
28	..	..	5·2	0·2	**91**	..	..	**28·6**	**0·2**
30	..	..	4·4	0·0	**92**	..	**5·6**	**49·2**	..
31	..	1·0	3·2	1·4	96	..	..	2·8	..
32	..	..	3·0	..	**98**	**0·0**	..	**6·8**	..
34	..	..	21·0	..	**99**	..	..	**72·4**	**0·2**
35	0·4	..	17·4	0·8	**100**	..	..	**26·8**	..
36	..	4·4	9·6	0·8	101	0·6	5·0	9·8	0·2
41	..	2·3	7·8	3·4	102	..	..	20·4	0·2
42	..	..	11·6	..	105	..	2·2	6·2	..
46	..	2·6	5·4	1·4	107	..	..	28·0	..
48	..	..	7·0	3·4	108	..	..	22·4	0·6
50	..	3·0	8·0	..	109	..	..	16·6	0·2
51	0·0	7·6	13·4	0·8	110	0·2	..	18·0	0·2
56	..	2·4	1·0	0·4	115	..	5·2	9·4	..
63	..	..	1·6	0·2	125	0·0	1·8	7·6	..
65	..	..	0·8	0·2	134	..	0·4	1·6	..
71	..	5·4	28·6	3·8					

Compartments were fogged in the late summer of 1957. Fogged compartments are shown in heavy type.

A check on the pupal count was therefore needed so that the final decision to control and the demarcation of the areas could be delayed until there was no longer any likelihood of a natural collapse of the population in the area.

From detailed studies into the epidemiology of *B. piniarius* carried out by the Forestry Commission Research Branch since 1956, it has become clear that quick and accurate assessment of early larval instars is most difficult (Bevan, 1957). The egg stage, therefore, was the latest one in which reliable figures could be obtained, and still leave time for effective control measures to be planned. Interpretation of the results of egg assessments necessitates the use of a 'critical number', i.e. that number of eggs above which it is considered desirable to employ a control, and here some guidance was to be had from Schwerdtfeger (1941) who gives a range of 600–2,500 eggs per tree to cover the four German Scots pine quality classes II–V, at age 30 years. In view of the low quality class and poor needle-holding capacity of the crop at Tentsmuir, a critical figure of 1,000 eggs per tree was chosen.

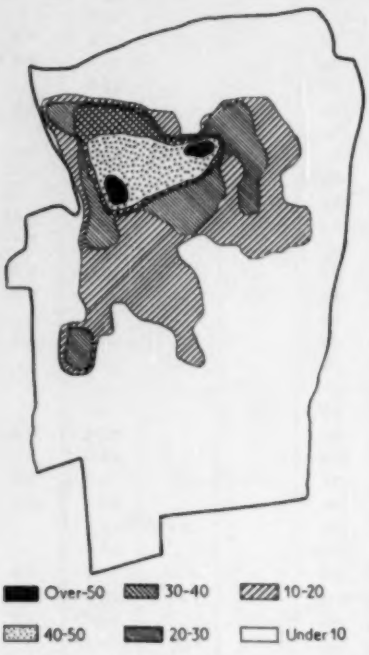

FIG. 2. Tentsmuir Forest. *Bupalus* pupal count. Number of pupae per square yard.

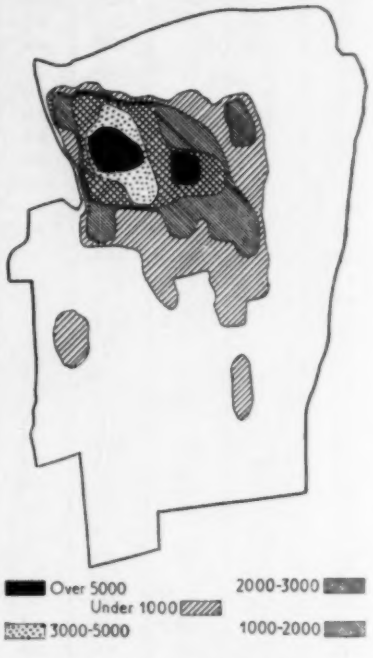

FIG. 3. Tentsmuir Forest. *Bupalus* egg count. Number of eggs per tree.

The female Pine looper's habit of staying closely to her place of hatch (Figs. 2 and 3) suggested that this characteristic might be used to advantage in the demarcation of area to come under control. By first establishing a pupal density/eggs deposited correlation based on limited egg sampling, and applying this to the pupal survey data, a great reduction in the total egg counting necessary was effected (this assumed that, for a given population density in any one year,

mortality factors would operate at roughly the same level throughout the area). In fact, it was subsequently found possible to carry out egg counts over the whole area later treated, and this provided a useful check on a method which it is felt would be of considerable value in a large infestation (Fig. 4).

The intention to treat only areas actually threatened should be noted. So far there has been no indication of just how many years an infestation of *B. piniarius* is likely to last in this country. Though the normal course on the continent seems to be 2 or 3 years of actual damage, there is no record of a high population being maintained in any one forest for more than a single year in Britain. For economic reasons, therefore, there could be little justification for embarking on a blanket treatment of the area as has frequently been done elsewhere. Restriction of the area treated also leaves that part of the surround unaffected by spray drift as a control, providing a comparison for treatment check and, more important, an untouched population whose natural development could be watched.

V. METHODS

Pre-Control Assessments

(i) The survey of pupae is shown on the map (Fig. 1). This survey was merely an extension of the normal annual routine, whereby the mean of the counts from 5 quadrants of 1 sq. yd. is taken as the compartment count. The first of the additional samples were made in compartments neighbouring those originally visited, and by the time this had been done it was fairly obvious that, apart from a few isolated high numbers, the dense population was confined to a small area in the north-west of the forest. The extent of the danger area was then investigated by continuing the sampling in all compartments which lay adjacent to those found with high densities and in which there were crops of a suitable age class, until a margin of low counts had been established.

(ii) The progress of adult emergence was checked by trapping adults as they left the soil. Five traps, each consisting basically of a small hessian tent covering 1 sq. yd. of soil, and surmounted by a screw-topped jar, were placed out equidistantly across the area selected. Compartment 99 was chosen because of the high population (72·4 pupae per sq. yd.) present there.

The data collected showed that about 60 per cent. of the total population as indicated by the pupal count emerged successfully. Emergence reached a maximum on 7th July and finished by 26th July.

(iii) Egg assessments are shown in Table II and Fig. 4. Up to a maximum of ten randomly chosen trees were sampled per compartment, the precise number depending on the labour force available at the time.

Three single-branch subsamples were taken from each tree as follows:

1. One from the 'lower' whorl, i.e. the whorl *above* that on which all the tree branches have some green needles.
2. One from the 'upper' whorl, i.e. the highest whorl on which all the branches were accessible, or the third whorl from the top, whichever was the lower.
3. One from the 'mid' whorl, i.e. that whorl nearest the point mid-way between the upper and lower whorls.

The selection of the branch within each whorl was kept as objective as possible. The one taken from the lower whorl being the nearest to the climber, from the mid-whorl the first branch occurring on the right of a vertical line through the base of the lower sampled branch, and a similar spiral movement was made to determine the branch to be chosen from the upper whorl. The sample branches were cut and brought down carefully from the crown and egg counting was carried out on the spot. A mean of the three samples was taken and a figure for the whole tree calculated by multiplying this mean, first by the number of branches in a whorl, and then by the number of live whorls on the tree. The compartment figure for the number of eggs per tree was taken as the mean of the totals for all the sample trees.

These assessments started in mid-July and finished at the end of August, just before the control fogging started. Initially the work was confined to nine compartments chosen so that the full range of pupal counts were represented and from this the progress of oviposition could be watched. The results of all the egg counts are summarized in Table II and represented graphically in Fig. 4. From this it can be seen that the critical egg count of 1,000 eggs per tree was always obtained from compartments with pupal numbers of 25 pupae per sq. yd. and over, and in one case where the figure was as low as 17·4 pupae per sq. yd.

(iv) A by-product of this work was the data upon the progress of egg-hatch. The mean percentage hatch was noted for each compartment sampled and the information gathered provided a useful check upon the previously estimated safe date for the start of control operations. In 1957 the hatch started about 20th July and was completed within a month.

TABLE II. *Bupalus egg counts*

Compt. no.	*No. of pupae per sq. yd.*	*No. of eggs per tree*	*Compt. no.*	*No. of pupae per sq. yd.*	*No. of eggs per tree*
7	22·0	382	80	19·2	848
21	12·2	686	81	15·0	501
22	7·2	176	82	40·2	4,866
26	7·8	484	83	40·2	5,042
27	19·8	1,041	84	32·4	3,499
28	5·2	649	88	32·0	2,262
29	..	409	89	49·6	2,668
31	3·2	258	90	27·4	1,791
34	21·0	302	91	28·6	1,576
35	17·4	1,160	92	49·2	3,476
36	9·6	569	93	17·8	980
71	28·6	1,087	98	6·8	831
72	23·6	2,681	99	72·4	3,280
73	15·8	429	100	26·8	2,051
74	21·4	1,146	101	9·8	301
77	23·6	2,864	102	20·4	519
78	42·0	7,520	107	28·0	1,737
79	56·0	2,532	108	22·4	711

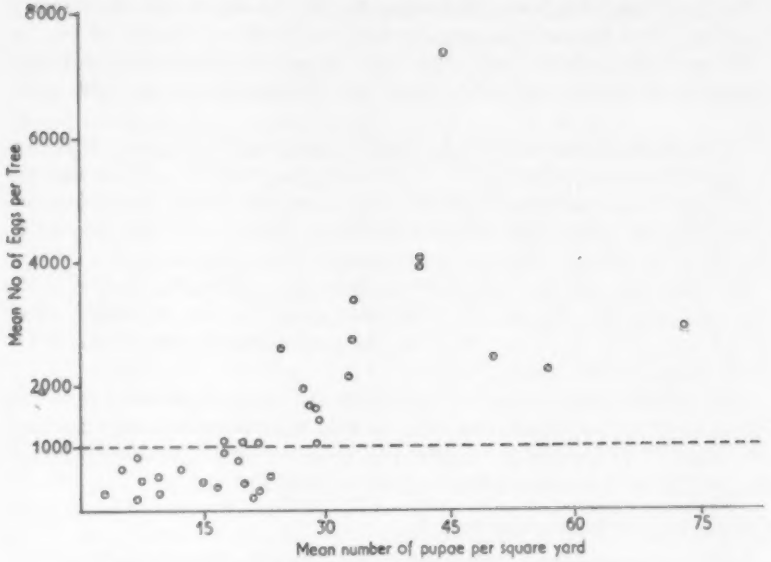

FIG. 4. Tentsmuir Forest. Number of eggs per tree/pupae per sq. yd.

Post-Control Assessments. Mortality

1. *Larval drop*

The kill was determined by counting the larvae falling onto 1 sq. yd. trays placed beneath the canopy of the compartment sampled. Normally ten, sometimes five, trays of tarred hessian on lathe frames were put out in grid formation. Counting was started the morning following treatment and continued daily until no further drop occurred.

TABLE III. *Post control larval drop*

	Cumulative numbers of larvae per square yard in: Compartment no.									
Date	*100*	*99*	*92*	*90*	*88*	*82*	*84*	*83*	*79*	*78*
29th Aug.	158·4	60·9	..	..	..	..	..	..	..	..
30th Aug.	170·0	77·6	..	..	..	..	..	..	..	..
31st Aug.	172·8	78·4	..	75·8	..	..	..	..	..	..
1st Sept.	176·0	79·9	..	87·2	..	..	..	..	..	..
2nd Sept.	177·4	81·0	..	92·9	98·0	113·8	67·8	112·6	..	..
3rd Sept.	177·6	81·1	..	94·1	102·4	143·2	79·5	133·0	..	..
5th Sept.	178·2	81·6	..	98·0	103·6	158·8	100·7	146·2	..	..
6th Sept.	178·6	81·6	..	100·4	106·2	161·6	118·2	148·2	87·2	147·6
7th Sept.	..	..	..	102·0	108·8	173·0	125·1	160·0	116·4	180·5
9th Sept.	..	..	..	105·3	117·6	183·6	137·5	166·0	135·0	211·5
10th Sept.	..	..	..	105·6	120·0	184·4	139·1	167·6	136·4	213·0

The cumulative numbers of larvae per sq. yd., calculated from the numbers dropping in each treated compartment sampled, are given in Table III.

The trays were placed 3 or 4 days before fogging so that the natural fall of larvae from the crown could be recorded. This was found to be a negligible quantity.

In compartments 99 and 100, which were fogged on 28th August, a high percentage of the larvae fell on the first day after fogging, and only very few after the second day. In compartments 90 and 88, fogged on 30th August and 1st September respectively, most of the larvae also fell in the first few days after fogging. In the remaining compartments, however, the fall of larvae was slower.

The collection of larvae provided an opportunity for determination of the stages in larval development at which the population was controlled. First, second, and third stages were found in the proportion 1:57:21, a total of 157 larvae having been examined.

Spot-check fogging was done after completion of larval drop in order to test the kill. Trays were placed under the group of trees to be re-treated and a considerable overdose of insecticide administered from the small portable 'Swingfog' machine. In no case was an additional fall of larvae observed.

2. *Final pupal survey—winter 1957–8*

A slight extension of the routine annual pupal survey was made to give as full a check as possible on the efficacy of the control operation. The results appear in the 1958 column of Table I. In no treated compartment was the count in 1958 more than 0·2 pupa per sq. yd., a figure which represents the finding of a single pupa in the five quadrats sampled. In fact, on examination of these pupae, one was found to be empty and the remaining two were parasitized.

The absence of a population in untreated parts of the forest, particularly those to the east of the fogged area (many of which bore high counts at the time of the 1957 survey) was to be expected. Under inversion conditions there is little upward movement and resultant loss of fogging material (see VI. Fogging), the cloud tending to drift steadily as a bank in the direction of the prevailing wind. During the operation the fog drift was normally towards the east, and it is, therefore, not surprising that its insecticidal effect extended in this direction for a considerable distance.

There was probably a downward trend in population level from 1957 to 1958 but pupal counts in parts of the forest too distant to have experienced drift suggest that there was no collapse during this period. For example, compartments 31, 41, and 48 in the south-east section of the forest only halved their pupal density.

VI. FOGGING

As this was the first occasion on which a control by fogging had been carried out in one of Britain's forests, a brief description of the equipment and its operation are given here. Fogging was done at night with a Tifa (Todd Insecticidal Fog Applicator). This machine has been widely used in the fumigation of warehouses, &c., and the special technique required for its use in forestry has been largely

developed by the Germans in post-war years. They have found that economically it compares favourably with spraying from the air, and the fact that the low initial capital cost allows ownership of the machine by the forest authority has obvious advantages over other methods which involve reliance on outside spraying contractors. A single machine can treat about 150 acres in one night.

The Tifa, which weighs about 650 lb., is a fairly bulky object to transport and a manœuvreable trailer is essential. In this case a Tasker ¾-ton, two-wheeled Land Rover trailer chassis was adapted to carry the machine at the rear, two 40-gallon drums of insecticide in front, and tins for 10 gallons of petrol in racks on the side. Timber carriage wheels were substituted for the road wheels normally fitted, and these gave added stability to the fully loaded trailer on rough roads. Pulled by a D.2 caterpillar tractor, the outfit performed satisfactorily and no modifications are now considered necessary.

Tifa produces a 'thermal fog', a term descriptive of the cloud's mode of manufacture rather than its nature. In brief, the fog is emitted from a distributor head or nozzle where metered quantities of insecticide, under pressure, meet a blast of hot gases resulting from the burning of petrol in a combustion chamber. The droplet size of the fog may be adjusted up to a maximum of 200 μ, and, at this size, a so-called 'wet' fog is produced, i.e. a damp deposit soon appears on the hand if it is placed in the cloud a foot or so from the distributor head. As the droplet size is decreased, a point will be reached below which there is no such deposit, and the emission is then termed a 'dry' fog. At this point (about 20 μ droplet size) the fog gives the most satisfactory performance in the forest. The rate of emission is established for a given formulation by disconnecting the insecticide supply pipe to the distributor head, and collecting the discharged material in a measuring vessel over a timed period; in this particular case, for instance, it turned out to be 23 gallons per hour. Knowing the emission rate and the width of the swathe to be treated, any required rate of application may be obtained by adjustment of the machine's speed of passage through the forest.

The fog leaves the distributor head with considerable momentum, but the mass of the droplets is small and the initial velocity is soon lost. Further dispersal depends on external conditions. The cloud has to expand and travel a distance equal to the swathe width, without appreciable loss through the canopy. In normal weather loss will be immediate and once through the crowns the cloud will be caught up by the wind and disappear. Under conditions of inversion, however, this does not happen. An inversion, although from the ground in open country, appears to be from the crowns of the trees in a forest; and thus, in an even aged stand, radiation from the near flat-topped canopy forms a cold layer of air on top of the crop. As the air becomes cooled, it must slowly sink and mix with the warmer air beneath, but as long as radiation persists, the air in contact with the radiating surface will always be the coldest and will continue to form an effective seal.

Theoretically inversions occur at night under clear skies and conditions of nil wind. In fact, the air is seldom entirely without movement, there always being a slight tendency for the mass to move slowly. At Tentsmuir the start of an

inversion was characterized by a fairly changeable wind, but this normally steadied down as the night progressed. The movement is an important factor in the proper distribution of the expanding fog cloud, and, as each successive swathe should be upwind of the previous one treated, the plan for the night's operation must include provision for any change of wind. The swathes will normally be about 100 yards wide but under good conditions excellent control can still be obtained with ease up to 200 yards from the machine.

The behaviour of the fog during a fogging operation is checked by one or two observers armed with torches. Standing at the far side of the swathes with torch shining upwards, an observer can see the fully expanded fog drifting over the sky as a blue haze. It may take 2 or 3 minutes to reach him, but by the time it does, the whole swathe width will be filled with the material.

An inversion will begin losing stability just before dawn breaks and immediately becomes obvious by escape of the fog from the crowns. Shortly after this stage the cloud, instead of rolling away filling the space between ground and canopy, begins to drift as a mass upwards a short distance from the machine. Horizontal movement of the material ceases, and dispersal through the canopy is immediate and complete.

That the low volume (in this case a gallon of 10 per cent. D.D.T. solution per acre) application of insecticides by fogging is an efficient method of control can be seen by reference to the post-control larval drop (Table III) and the pupal counts for 1958 (Table I). However, reference to the map (Fig. 1) which records the dates of treatment of the various compartments shows how much time can be spent waiting for the right conditions. The team of workers is small, an operator, a tractor driver and two observers—but these may well have to wait for days on end if the weather happens to be unsuitable.

Climate and terrain must both be considered before making a choice of control method. A last-minute decision on egg-counts may cause difficulties with aerial spraying contractors. On the other hand, for fogging, additional racks may have to be cut for the passage of the machine.

ACKNOWLEDGEMENT

Mr. R. C. Kirkland's invaluable help throughout is gratefully acknowledged.

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SOME COMMON MOSSES AS INDICATORS IN FORESTRY

I. G. HALL

(*Forestry Commission*)

SUMMARY

Twenty-five common mosses are described individually and each illustrated by a line drawing. Those growing under acid conditions are described first, followed by those growing under basic conditions. Notes on habitat and on soils are given for each moss and its value as an indicator of forest conditions, and so as an aid to the choice of species, is considered.

IN these notes the habitats and major identification features of twenty-five of the commoner mosses, most of which occur in woodland, are briefly described. The species have been arranged broadly in accordance with their relation to soil acidity: those which grow under acid conditions are described first, those which grow under basic conditions last. The correlation between soil acidity and species is only approximate since some of those described may grow under a fairly wide range of conditions. In practice, therefore, conclusions drawn relating to the environmental conditions of any site should be based not on one species alone but on all those present, together with their vigour and relative abundance.

Soil acidity and the important distinction between mull and mor soils, i.e. brown earths and podzols, can be closely correlated with certain mosses. Soil acidity is not of course the only factor relating to choice of tree species to plant. It should be mentioned, therefore, that mosses often indicate quite closely such factors as soil moisture, soil texture, atmospheric moisture, and the effect on this of wind.

Mosses, lacking roots, are strictly only indicators of conditions in the upper soil layer and particularly the humus layer. Nevertheless, their importance as site indicators cannot be dismissed because of this limitation since conditions in the upper soil often indicate those deeper down. Mosses, which in some cases are the only species of natural vegetation present are, in my opinion, just as useful as flowering plants in indicating site conditions.

One example, where the upper soil differs in acidity from the lower, may be quoted as an illustration of the usefulness of mosses as site indicators. *Dicranum scoparium* which, when abundant, is a fairly accurate indicator of acid conditions, is sometimes found on chalk downs, especially on exposed sites. In such cases soil examination will often disclose that the upper soil layer is becoming leached and acid even though the underlying soil is strongly alkaline.

Most of the species described here are illustrated in *Woodland Mosses* (Watson, H., 1947). For those who are really interested either *British Mosses and Liverworts* (Watson, E. V., 1955) or *The Students Handbook of British Mosses* (Dixon, 1924) is indispensable. Only the most obvious identification features, suited to a hand lens, are given in this paper. With experience the majority described can be recognized at a glance. The Appendix gives the frequency of the species described

in different types of woodland and is taken from the two papers by W. Watson (Watson, 1936).

Rhacomitrium lanuginosum. In its most typical setting this species is associated with high altitude peaty moorlands and upper mountain slopes where it is often very abundant. Where the soil is poor and exposure severe it is occasionally found at comparatively low altitude. Often abundant on rocks and stone walls it is also common on thin rocky soils, where it may form extensive *Rhacomitrium* heath. I have seen it most commonly in the north though it also occurs on the granite 'tors' and high hills of the west of England, such as Brown Willy in Cornwall. Sheep are not averse to it and in Lapland it is an important adjunct to the food of the reindeer. In the past *Rhacomitrium* sites were wont to be dismissed as unplantable. Present day cultural techniques however may, depending on the dominance of *Rhacomitrium*, permit afforestation with the least exacting conifers. Although there are a number of *Rhacomitrium* species, *R. lanuginosum* can hardly in its typical form be mistaken for any other. Generally it grows in loosely felted mats which often spread over rocks or soil to a considerable distance. In the mass, the long hair points to the leaf impart a characteristic hoary grey coloration. Closer examination will disclose the underlying dull greenish colour of the leaves. The individual stems are long and straggling.

Leucobryum glaucum. Wherever this moss is found in abundance it may be taken as a very reliable indicator of leached and acid soil conditions. It seems especially common on sandy, podzolized soils. On such soils, especially on old pine sites, but sometimes also on heavier soils under old oak and beech, it may be the only natural vegetation present. Raw acid humus forms an ideal growth medium. Although occurring in the open on both dry and wet sites, especially with heathy vegetation where it sometimes grows with *Sphagnum*, it is perhaps more common on shady sites. It is commonly associated in the north and west of England with *Deschampsia flexuosa* under oak, where cool moist conditions obtain. As an indicator it strongly suggests that only the less exacting conifers will be suited to the conditions.

This moss cannot possibly be mistaken for any other. The neat, rounded cushions and the pale whitish-green colour are highly characteristic. The colour of the stems below is a dirty grey, while the leaves are closely set and appear blunt. On the oldest cushions the annual growth increment of the stems is evident. Sometimes the cushions coalesce to form large patches several feet in extent.

Pleurozium (Hypnum) schreberi. This species is often very abundant, together with *Hylocomium splendens*, on Calluna moorland where it forms an extensive ground carpet. It does not appear to be especially tolerant of shade, being commoner in open than in closed woodland, and under 'leggy', senile *Calluna* than under young and vigorous *Calluna*. In addition to moorland and heath sites it also occurs on the margins or in the more open spaces in many types of woodland on acid soils. Less typically it occurs on open grassy sites which are only moderately acid. Despite some catholicity in choice of habitat I have never seen it really abundant on other than distinctly acid sites suited to the growth of unexacting conifers.

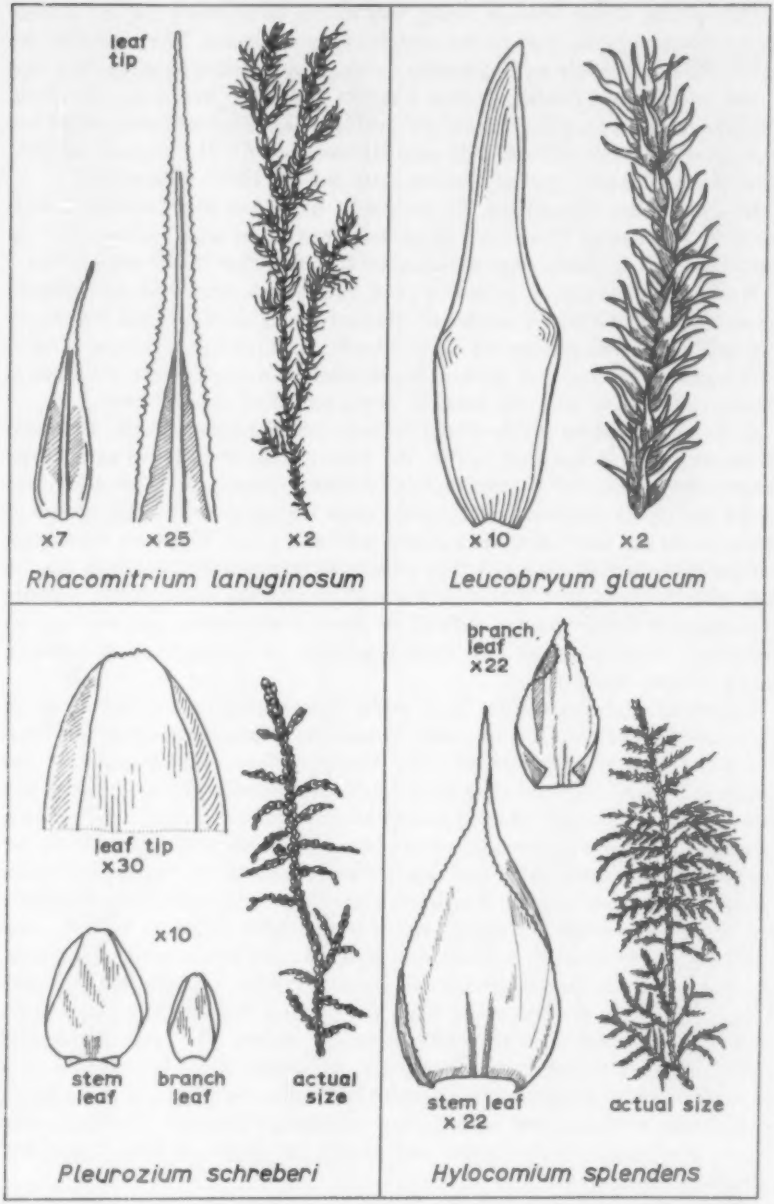
leaf tip
x7
x25
x2
Rhacomitrium lanuginosum
x10
x2
Leucobryum glaucum
leaf tip x30
x10
stem leaf
branch leaf
actual size
Pleurozium schreberi
branch leaf x22
stem leaf x 22
actual size
Hylocomium splendens

FIG. 1

This species, either dead or living, will hardly be mistaken for any similar species if attention be paid to the conspicuously red stems. The colour of the leaves, which are closely set, is generally a pale green or yellowish green. The tips of the branches are drawn out into a rather fine point. When dry the plant might be mistaken for either *Pseudoschleropodium* (*Bracythecium*) *purum* which has more swollen shoots and minutely pointed leaves, or for *Hylocomium splendens* which has a markedly prostrate growth habit and also differs structurally.

Hylocomium splendens. As previously mentioned this species is a very common associate of *Pleurozium* (*Hypnum*) *schreberi* on acid *Calluna* moor or heathland. It is probably more abundant on such sites than in any other habitat. It is also quite common in upland oak and birch woods often with *Deschampsia flexuosa*. I have also seen it frequently growing among short turf and sometimes also on leached chalk grassland or old scrub soils. It is in fact something of a 'wide' with regard to its choice of habitat. Nevertheless, this species when abundant is usually indicative of acid soils unsuited to the growth of exacting trees.

A distinctive feature of this species lies in its peculiar growth habit. The main stems are more or less flattened to the ground but, at intervals along their length, shorter erect or slightly arching subsidiary shoots arise. The older parts of the plant are a dull, rather dark green, while the young shoots and the tips of the branches and main stems are a shining yellowish green. The stems are reddish and are also clothed with countless minute leaves (paraphyllia) which can be seen with the hand lens. It is these latter which give the whole plant a peculiar appearance of foliage density, difficult to describe adequately, but very typical and easily recognized even with dried specimens. It is unusual in its twice or thrice pinnate branching.

Polytrichum commune. This species is most abundant where the soil is distinctly wet and acid. It is especially common on upland peat bogs in the north and west, often growing with *Molinia*, *Juncus*, *Calluna*, and *Sphagnum*. It also occurs in lowland bogs and sometimes in wet open woodland, though not to the same extent as in upland peats. Apart from the wetness and lack of soil aeration indicated it is not a species indicative of especially unfavourable conditions for tree growth, particularly after draining, of Sitka spruce. All the *Polytrichum* species are easily recognized as such. They have a large number of stiff leaves which give the single stems much the appearance of small conifer seedlings. Indeed, some species so closely simulate coniferous seedlings as to be left in weeded seed beds. *P. commune* is the largest species, sometimes attaining a height of more than 1 foot. The leaves are dark green, long, and pointed. Frequently it forms large, rather loose carpets associated with *Sphagnum* mosses. The large four-angled spore capsule is characteristic. It could in its shorter forms be confused with *P. juniperinum* which, however, has untoothed leaves. In its typical bog habitats it ought not to be confused with *P. formosum* which although it also has toothed leaves, is of much shorter stature and usually also grows on drier, heathy and woodland sites.

Plagiothecium undulatum. Although occurring in regions both of high and low rainfall this species is, in my experience, commoner in the wetter parts

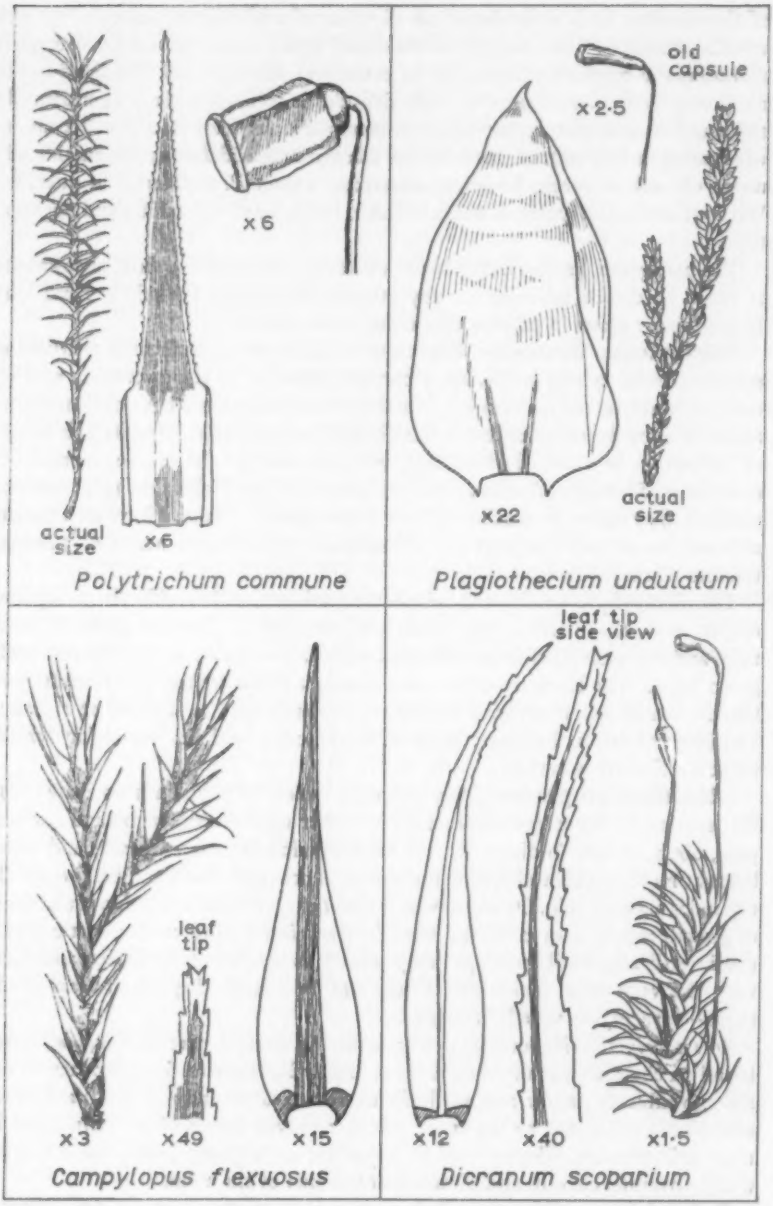
actual size
x6
x6
Polytrichum commune
old capsule
x2·5
x22
actual size
Plagiothecium undulatum
leaf tip
x3
x49
x15
Campylopus flexuosus
leaf tip side view
x12
x40
x1·5
Dicranum scoparium

FIG. 2

of the country. It is to be found on all types of acid soil, on peat, and on raw woodland humus. Some degree of woodland shade seems favourable though it also occurs in open moorland sites. In coniferous, birch, or oak woodland in the north especially at moderate or high altitudes it seems especially abundant. In the south it does not appear to be so common or at least does not become so widespread and abundant. Some of the leached and acid Lower Greensand soils under old oak or beech, however, sometimes attract *P. undulatum* in quantity. Without doubt this species is a most reliable indicator of soil acidity and degradation.

The pale green, flattened fronds are unlike any other moss so that, once known, it could hardly be mistaken for any other even without use of the hand lens. Sometimes it grows in patches extending to several feet.

Campylopus flexuosus. Short turf in the open at fairly high altitudes or open spaces in upland woods are a common habitat. It also occurs on sparsely covered banks, on old rotten stumps, and on lowland heaths. I have the impression also that some degree of exposure is indicated by this species. Despite this variety of habitat, it is a reliable indicator, when present in abundance, of acid soil conditions. Though such sites appear unsuited to the growth of the more exacting conifers, they might in mixture achieve lower quality classes. I have seen reasonable old beech and also larch on well-drained upland sites where *C. flexuosus* was the dominant moss.

The *Campylopus* species are, without experience, rather difficult to separate one from another without the aid of a microscope. *C. flexuosus* grows in dense tufts and the individual stems are small with narrow green or slightly yellowish-green leaves. The lower dead leaves are usually a characteristic warm vinous-red. On the whole this is rather a variable species not easy to identify at a glance. Familiarity with it, however, taken in conjunction with its habitation renders identification fairly certain.

Dicranum scoparium. A rather wide variety of habitats is associated with this species. It is perhaps commonest in rather open heathy woodland carrying pine, birch, or oak. Additionally it is also to be found on open heaths and moorlands at moderate altitudes, and also among short chalk downland turf where the top soil is actually acid. On the downs it does not attain the stature and luxuriance of growth that it does in heathy sites. *D. scoparium* is most characteristic of acid and infertile, especially perhaps sandy soils. It is not, however, usually associated with the very worst conditions. Pines, and to a lesser degree—at least in the south—spruces, are usually indicated.

D. scoparium varies somewhat but, with the exception of *D. bonjeani* (often found on chalk downland), should not normally be mistaken for any other. It can also resemble *D. majus* and small forms of the latter may be confused unless attention be directed to the more strongly curved leaves of *D. majus*, and its more robust habit. The tufts of *D. scoparium* are a glossy green, the leaves are usually narrow, curved, and directed to one side of the stem.

Polytrichum piliferum. This species is most abundant on dry, siliceous acid soils such as are found on many heaths. On bare shallow soils in such habitats

it forms locally dominant colonies with but few other moss species present. In woodlands it is much less widespread though still occurring among short turf or around the boles of old trees. Disused pit heaps, ashes, cinders, and similar dry and acid habitats are also much favoured. In the wetter parts of the country it will be found on weathered rocks bearing a thin cover of peaty soil. Where *P. piliferum* is abundant pines are indicated and the possibility of seasonal soil dryness should be borne in mind.

This is one of the smallest of *Polytrichum* species, in addition the tips of the leaves have a fine hair-point. The individual plants are only about an inch tall; their colour is glaucous green. The hair points may be seen with the naked eye and render this plant easy to identify.

Dicranella heteromalla. Bare, rather dry, sandy or loamy soils which are acid to moderately acid are the most favoured by this species. It appears to be commonest where some shade is present and for this reason is often abundant in woodlands, especially around the boles of old trees. Though noted on bare heaths it is, in my experience, commoner on wooded heath, especially where birch, pine, or oak are present. Roadside banks, especially under trees, are also sometimes dominated by this species. *Mnium hornum* is a common associate on the rather less acid sites. Where present in abundance *D. heteromalla* indicates that pines, and perhaps oak and less exacting hardwoods will grow.

D. heteromalla occurs in flattened sheets though small colonies are slightly rounded in outline. The numerous individual plants with their narrow, curved, shining green leaves are closely packed together and do not generally exceed ½–1 inch at most in height. When dry, the capsule is rather distinctive because of its deep longitudinal furrows.

Polytrichum formosum. This is a moss which is common on soils ranging from acid to mildly acid. It is very characteristic of old, rather open, oak and beech woodland either on bare soil or among turf. It occurs on both dry and wet soils. On the more open heathy sites its place seems to be usually taken by the allied *P. juniperinum*. This is a not unpropitious indicator and on sites where it is abundant larch and Douglas fir often grow well.

To the typical *Polytrichum* appearance may be added the fact that the margin of the leaf is sharply toothed. *P. juniperinum* which it resembles lacks the toothed margin to the leaf edge which is also strongly inrolled.

Mnium hornum. Few people can have failed to notice this species in woodlands of almost all types and it is generally one of the first mosses whose name is learnt. To its general abundance may be added its rather wide tolerance in relation to soil texture and acidity. Despite this *M. hornum* is most typical of moderately acid soils and is very common under oak, beech, and birch in the lowlands and in mountainous districts. Outside of woodlands, except on some tree-covered banks, it does not assume prominence, seeming best suited to cool, shady conditions. As an indicator it suggests that the choice of tree species may be fairly wide and may allow both the less exacting broad-leaved trees and coniferous species, at least in mixture.

There are none of the commoner mosses, and but few of the rarer, which can be mistaken for *M. hornum* when the leaves are moist. It is a gregarious species

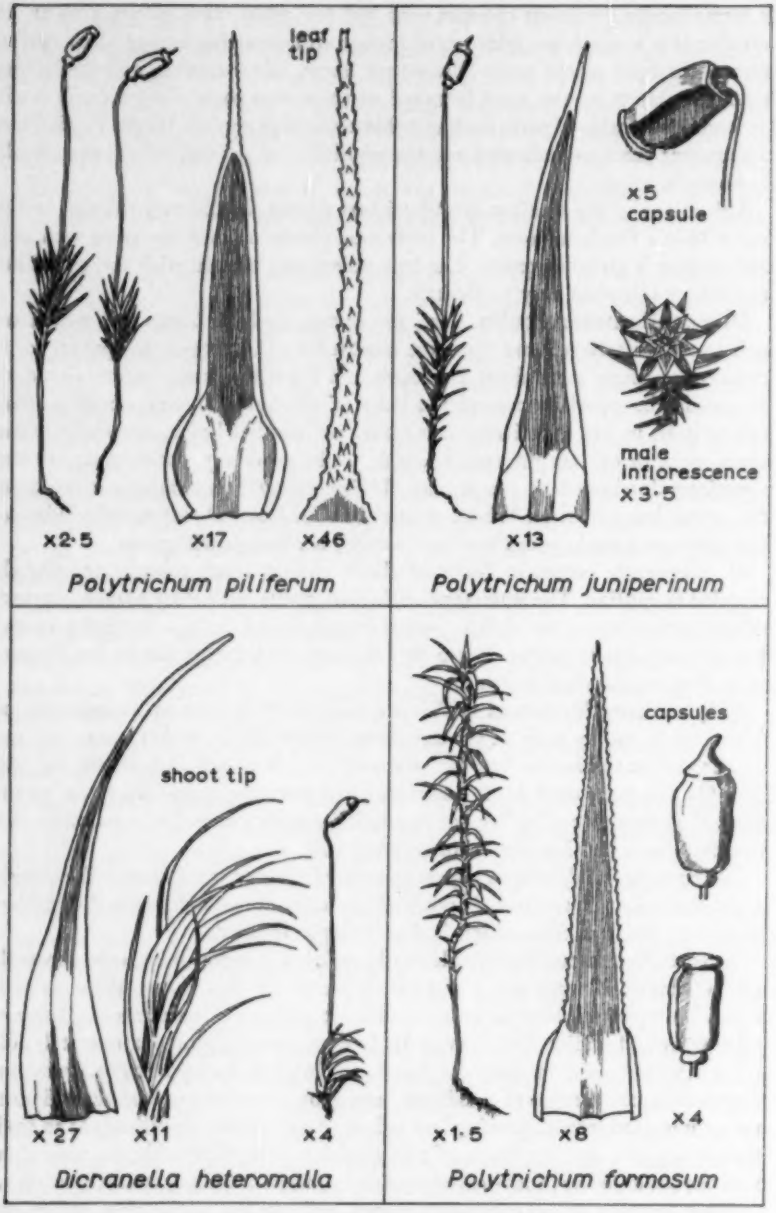
leaf tip
x2·5
x17
x46
Polytrichum piliferum
x5 capsule
male inflorescence x3·5
x13
Polytrichum juniperinum
shoot tip
x 27
x11
x4
Dicranella heteromalla
capsules
x1·5
x8
x4
Polytrichum formosum

FIG. 3

growing in dense rather deep green patches, not over 1–2 inches tall. The double row of spinous teeth to the leaf margin is noteworthy.

Hypnum cupressiforme. Of all our mosses this is one of the most abundant and widely distributed over many different habitats. These include lowland and mountain woodlands, moorland with such mosses as *Hylocomium splendens* and *Pleurozium* (*Hypnum*) *schreberi*, heaths, hedgebanks, and among short turf of varying type. Within this range it is commonest on the ground but is also not infrequent on the trunks of trees (var. *filiforme*), on rocks, boulders, walls, and roofs. Corresponding with this range in habitats is its equally wide tolerance of soil conditions which range from those which are distinctly acid to those which are alkaline. It must be confessed, therefore, that *H. cupressiforme* is more liable to confuse than enlighten. If, however, one has knowledge of its varieties it can be quite helpful. Apart from the so-called 'typical form' which is commonest in moderately to slightly acid woodland the two most useful varieties to know are the var. *ericetorum* and the var. *lacunosum*. The first, var. *ericetorum*, as its name suggests, occurs on heaths and moorlands, usually with *Calluna*. The latter, var. *lacunosum*, on the contrary, occurs on basic or calcareous soils. I have seen it very abundantly on recently deposited pit heaps where the pH value has been around seven.

Although a most variable species it is not really difficult to recognize a moss as belonging to the *H. cupressiforme* group, even if the exact variety be more doubtful. Both the typical form and its varieties have overlapping, closely set, curved, finely pointed leaves. The degree of robustness and width of leafy shoots is most useful in identifying the varieties, and the habitat will of course constitute a useful indication.

H. cupressiforme itself is green to yellowish green and of procumbent habit. The var. *ericetorum* is paler, when dry almost yellow, and with a characteristic glossy sheen. It has, compared with *H. cupressiforme* itself, an erect or semi-erect growth habit; the stems and branches are usually markedly flattened in one plane, almost like a *Plagiothecium*. The var. *lacunosum* also has an erect growth habit and is a very well-marked variety. Both stem and branches are much swollen and of a rich greenish-gold colour. To my mind, the few branches which it has render it not unlike *Pseudoschleropodium* (*Brachythecium*) *purum*, but in any case it will hardly be confused with any other of the *H. cupressiforme* group.

Thuidium tamarascinum. The typical habitat for this handsome moss is in cool, moist, shady woodlands especially, perhaps, those with a northerly aspect. On such sites it is often abundant and the loosely woven mats sprawling over the ground or on old rotten tree stumps are very conspicuous. Apart from woodlands it also grows among turf especially perhaps in the wetter districts of Britain. This species may be regarded as the dividing line between the earlier described mosses, which are not especially favourable site indicators, and those which follow which indicate the possibility of planting more or less exacting tree species. The soils it most affects are usually only moderately acid and often moist and loamy. Norway spruce, Douglas fir, and oak are often indicated where *T. tamarascinum* is abundant.

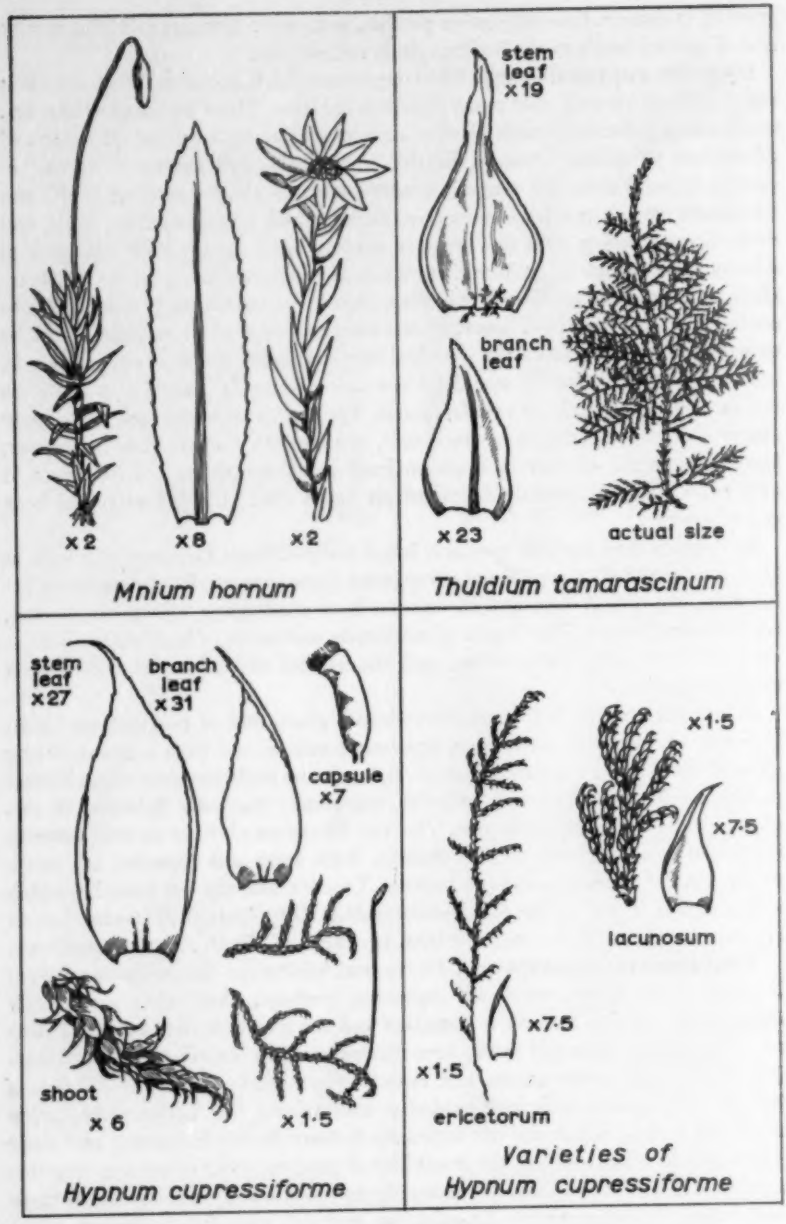
x 2
x 8
x 2
Mnium hornum
stem leaf x 19
branch leaf
x 23
actual size
Thuidium tamarascinum
stem leaf x 27
branch leaf x 31
capsule x 7
shoot
x 6
x 1·5
Hypnum cupressiforme
x 1·5
x 7·5
lacunosum
x 7·5
x 1·5
ericetorum
Varieties of Hypnum cupressiforme

FIG. 4

With the exception on occasion perhaps of *Hylocomium splendens* and one or two *Thuidium* species which are rarer or less widely distributed *T. tamarascinum* is quite unmistakable. The green or yellowish-green, feathery fronds are like miniature ferns and, because of their beauty, are often used by florists and others. They owe their character to non-glossy leaves and bi- or tri-pinnate branching.

Pseudoschleropodium (Brachythecium) purum. Equally at home in woodland and downland turf this species is one of our most abundant mosses. In woodlands it is very often found in lowland oak woods and the better spruce and larch plantations, provided shade is not too heavy. The soils on which it occurs are similarly varied including both wet and dry and with texture varying between sands and clays. It seems in my experience, though, to be rather less common on very sandy soils. It should be mentioned, however, that it often occurs together with *Pleurozium schreberi*, *Hylocomium splendens*, and *Hypnum cupressiforme* on heaths. On chalk downs it seems less robust and luxuriant as a rule, but is the most abundant moss in general in these habitats. On the whole *P. purum* can be regarded as a favourable indicator for other than exacting tree species.

The swollen blunt stems and branches taken in conjunction with the pale whitish or yellowish-green colour make this an easy moss to identify. Among short turf, it occurs in low, prostrate patches and so is often dominant where sheep or rabbits feed. Elsewhere the patches are more loosely felted together and are less procumbent. The fruit is very rare.

Atrichum undulatum (Catharinea undulata). This is another extremely common species which, though occurring in a wide variety of habitats, is most typical of woodlands. It is rather shade tolerant and for this reason is sometimes the only moss present on bare soil under heavy canopy. Moderately to mildly acid, rather heavy or loamy soils seem to suit this species very well. In addition to woodlands it occurs on shady banks, ditch sides, and similar habitats. The frequency with which *A. undulatum* is found in pedunculate oak woods suggests it is a species indicative of oak. Additionally, good conifer plantations as well as the less exacting hardwoods are often associated with it.

The loose, rather dull green patches should not be mistaken for any other species except possibly *Mnium undulatum*. The latter, however, has branched stems unlike the simple erect individual stems of *A. undulatum*, and therefore appears more diffuse and straggling as well as being taller. The leaves of *A. undulatum* are transversely undulate and the margins sharply toothed.

Rhytidiadelphus loreus (Hylocomium loreum). It is debatable whether this species should not have come earlier in the list. In mountainous high rainfall areas, at least, this is a woodland species often occurring abundantly among the turf under natural birch and sessile oak woods. Such woods, together with its frequency in some upland larch plantations, suggest that *R. loreus* is commonest on moderately but not severely acid soils and is a not unfavourable indicator. It is, I think, more useful as an indicator species at moderate to high altitudes where it is often associated with established plantations of unexacting conifers. In the south of England it is, in my experience, rather rare though appearing more frequently in the south-west.

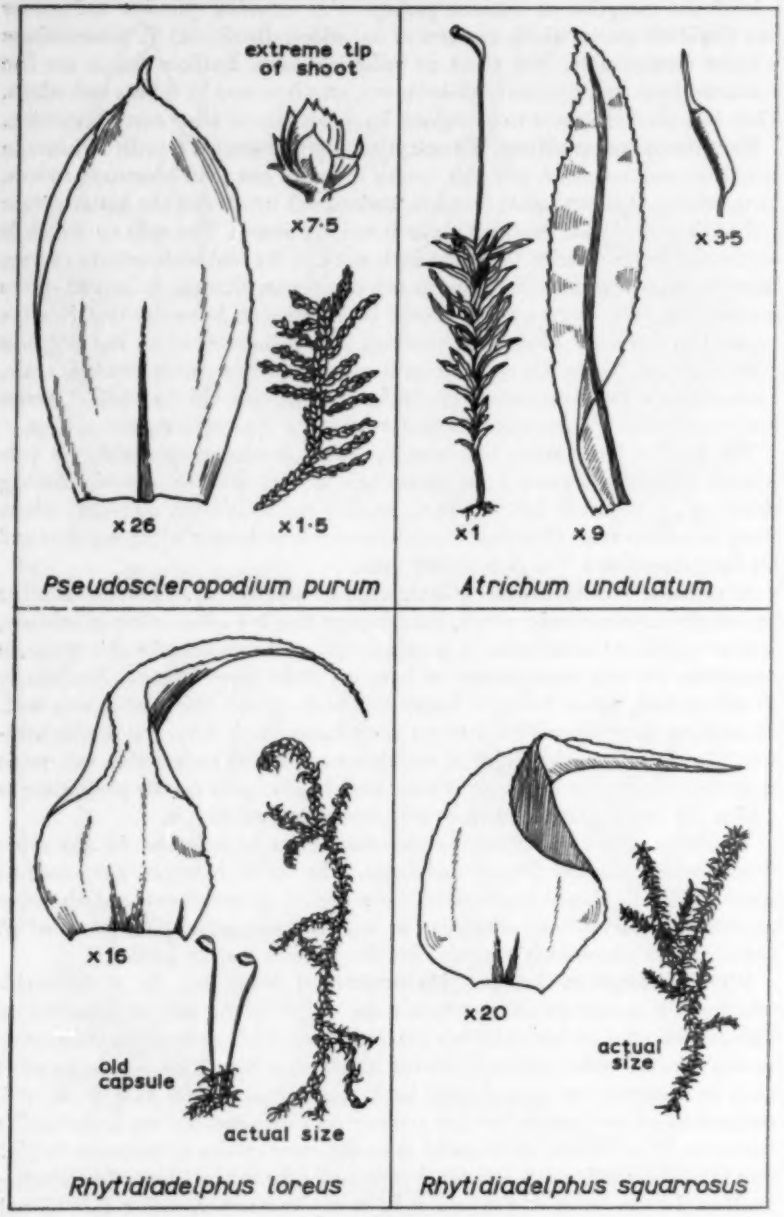
extreme tip of shoot
x7·5
x26
x1·5
Pseudoscleropodium purum
x1
x9
x3·5
Atrichum undulatum
x16
old capsule
actual size
Rhytidiadelphus loreus
x20
actual size
Rhytidiadelphus squarrosus

Fig. 5

This fine moss occurs in large, loose, often pure patches which scramble vigorously over the ground, usually among turf although also on wet boulders. The colour is a pale, glossy green or greyish green while the individual leaves are large, toothed, curved, and longly pointed. Individual stems are up to a foot in length and the branches are slightly bent downwards at the tips. Once known *R. loreus* will not be mistaken for any other moss, even without recourse to the lens.

Rhytidiadelphus squarrosus (Hylocomium squarrosum). This is much less a woodland species than *R. loreus*. It grows among turf over a wide range of habitats which includes chalk downs, lawns, fields, and woodland rides and glades; it may also occur among larch needles and other humus. It is tolerant of a wide range in soil acidity though, in my experience, not typical of excessively acid soils. As an indicator it suggests that a number of conifer species and the less exacting hardwoods will grow.

Among short turf which is much grazed, trodden, or mown this somewhat inconspicuous species may be overlooked. Elsewhere the stems, which grow closely together, may be 6 inches tall. There is, however, no other moss which has quite the appearance of *R. squarrosus*. The main feature is the strongly recurved leaves and the blunt apex to the stem due to the star-like 'spread' of the apical leaves. As a whole the plant is a rather pale green but the stems are reddish.

Rhytidiadelphus triquetrus (Hylocomium triquetrum). This species does not appear to be so generally abundant and widespread as *R. squarrosus*. In the north and west I have found it commonly in upland woodland. In the south it occurs in a variety of woodland ranging from birch and oak through to beech on rendziniform brown earths or clay-with-flints, and also ash woods. It also occurs, though to a lesser extent, in open situations such as woodland rides, hedgebanks, and hill sides. Loamy soils of reasonable fertility are generally indicated and, as already implied, clay soils of good base status often attract this species. I have not found it in any abundance on dry and rigorous sites. Some hardwoods or the better conifers may grow where this species is abundant and the associated flowering plants are taken into account.

R. triquetrus grows in loosely woven partly ascending patches of up to about 6 inches in height. The main stems which are tough and wiry are reddish as also, particularly, are those of the branches. In colour the leaves are yellowish-green to green, stiff, and roughly triangular in shape but with a drawn out, pointed tip. The branches vary in length and are dispersed all round the stem. Larger leaves above give 'tassel-like' tips to the shoots.

Cirriphyllum (Eurhynchium) piliferum. With this species we begin the list of those which are distinctly favourable site indicators. It occurs principally in woodlands though it is also found in fairly tall herbage on hedgebanks and similar rather shady sites. Loam and clay soils of moderate to good base status are most affected, generally where the moisture conditions are good. It often grows abundantly on heavy alkaline chalk and limestone soils but is virtually absent from acid soils. Oak with hazel, ash woods, and the like often attract it in abundance. Commonly *C. piliferum* grows among turf but occurs also on bare soil in shady woods. As an indicator it points to fertile hardwood sites.

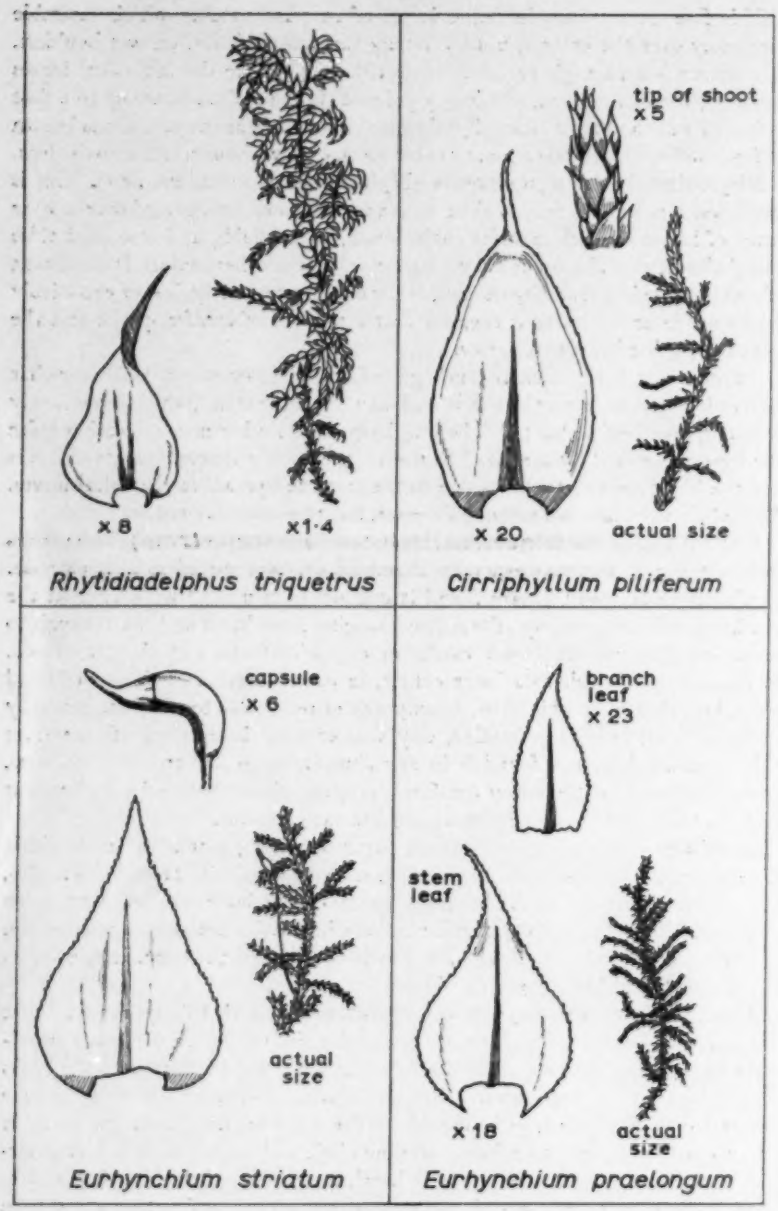
x 8
x1·4
Rhytidiadelphus triquetrus
tip of shoot
x 5
x 20
actual size
Cirriphyllum piliferum
capsule
x 6
actual
size
Eurhynchium striatum
branch
leaf
x 23
stem
leaf
x 18
actual
size
Eurhynchium praelongum

Fig. 6

Though somewhat inconspicuous the pale green loosely woven patches have an appearance all their own. On examination the most conspicuous feature is the leaf tip which is abruptly contracted into a long greenish 'hair'. The fruit is very rare.

Eurhynchium striatum. This and the preceding species occur in similar habitats and commonly grow together although *E. striatum* more frequently occurs on bare mineral soil. It is often abundant and sometimes dominant on good woodland mull soils such as occur under ash and in some beech, oak, and other plantations. It also occurs, though much less frequently, under hardwoods and conifers mixed, or even the latter alone. In replanting a former conifer area where *E. striatum* has been abundant it would be well to consider whether a hardwood should be planted. The soils preferred appear to be moist loams and clays of good base status. As with *C. piliferum*, the choice of tree species to plant is generally wide and will probably be confined to broad-leaved species.

E. striatum grows in loosely interwoven, straggling patches of a medium green colour. The branches are numerous, crowded, and somewhat sinuate and ascending. A distinctive feature of the triangular leaves when dry is afforded by the longitudinal furrows or crinkles. With a good lens the strong nerve reaching to above halfway and the finely toothed margin will be noted.

Eurhynchium praelongum. Though found in a wide variety of habitats, particularly as regards the pH value of the soil, it appears particularly at home in broad leaved, shady woodland. In my experience, it is especially associated with moist and heavy soils, e.g. the Gault and Weald clays which may be poorly drained. In addition to its woodland habitats, it also occurs in more open situations such as clay grassland, woodland rides, hedgebanks, on stones, and on old stumps and rotting timber. Although hardwoods, including ash, may often be indicated, some caution is advised in view of the seemingly wide tolerance of pH value of *E. praelongum*.

It is a rather delicate little plant which forms low, procumbent green or yellowish-green patches. The individual plants have fairly regular lateral branches which decrease in length towards the apex of the stem. In its more luxuriant forms it has a feathery outline reminiscent of small plants of *Thuidium tamarascinum*. A good spotting feature is the marked difference between the triangular stem leaves with their long recurved points and the ordinary branch leaves which are much narrower and smaller.

Fissidens taxifolius. This common moss is one which is very well worth knowing. It has a high degree of fidelity for heavy and loamy soils, being often very abundant on clay soils. Shady, moist woodlands are its especial habitat. The soils are always of good base status, neutral to alkaline and, at least in woodlands, well supplied with moisture. In such sites it grows on the bare mineral soil and may be the only species of natural vegetation present. Outside woodlands it may be found growing among short turf on chalk and limestone soils, also on hedgebanks. *F. taxifolius* can usually be relied on as an indicator that oak or exacting hardwoods such as ash will grow.

The individual plants comprising the flattened tufts are not above an inch in

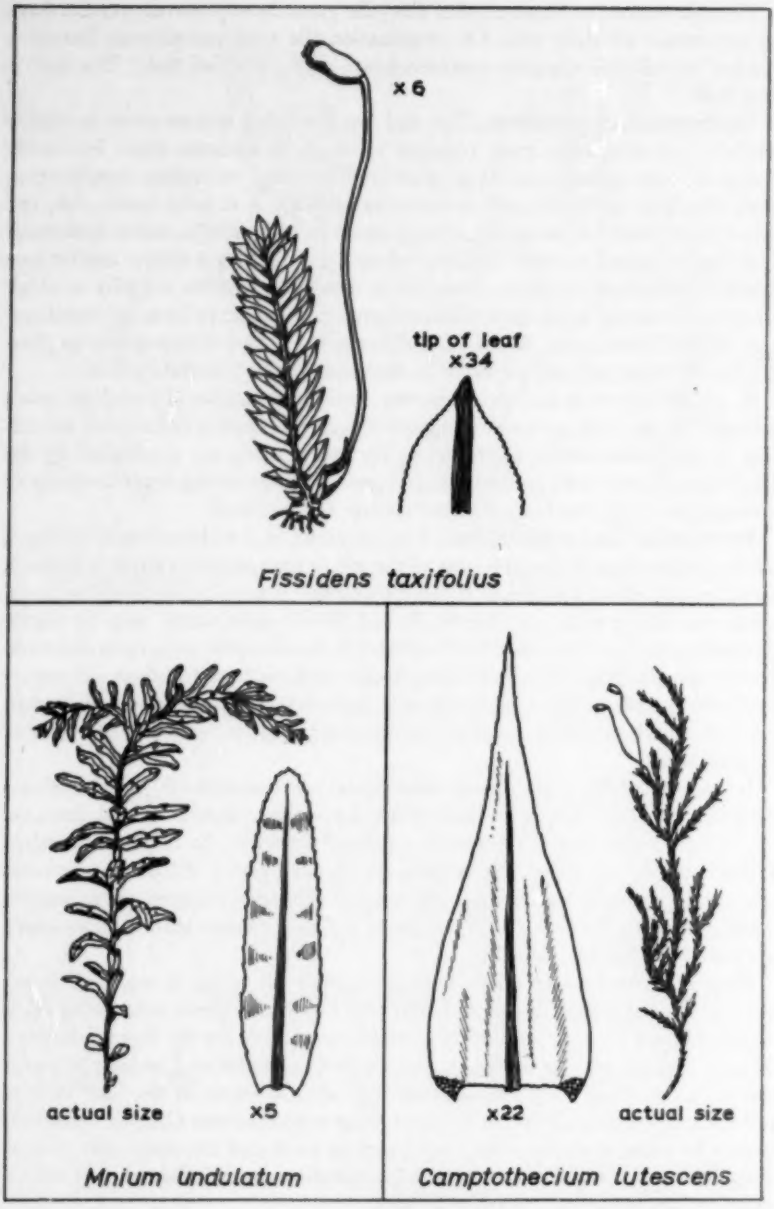
x 6
tip of leaf
x34
Fissidens taxifolius
actual size
x5
Mnium undulatum
x22
actual size
Camptothecium lutescens

Fig. 7

length and are themselves flattened. The leaves which are dispersed in two regular ranks on either side of the stem are a deep, rather dull green in colour. All the *Fissidens* species have this characteristic flattened appearance but *F. taxifolius* in its typical woodland habitat should not be confused. The leaf has a strong nerve which projects slightly beyond the apex. On chalk downland it may be difficult to separate without a microscope from the allied *F. cristatus*.

Mnium undulatum. Typically this species is most abundant on loamy, broad-leaved woodland soils where the soil pH value is around neutral. So far as my experience goes it prefers moist soils and may often be found on the edge of woodland streams. In woodland it also indicates mull conditions where there is good humus incorporation. In addition to shady woodlands it also grows under hedgerows, among blackthorn, hawthorn, and other scrub, and among luxuriantly growing wasteland grasses and flowers. Normally *M. undulatum* may be taken as an indicator of good hardwood conditions.

It grows in loose, straggling, pale green to yellowish-green patches and when growing abundantly in moist mully sites is exceedingly handsome. The branches are rather long and pendulous. All the leaves are fairly large, long, strap-shaped and of filmy texture; they have their margins toothed, and the nerve clearly marked. They are also, especially when moist, distinctly crisped by the strong transverse undulations. Fruit is uncommon.

Camptothecium lutescens. Although this is not a woodland species, it is very common and is the only marked calcicole with which these notes deal. It is abundant on chalk downs where it grows both among turf and on bare chalky soil. Elsewhere I have seen it on calcareous spoil heaps, among scrub ash, on old weathered mortar, and on shelly sand dunes. As its habitats suggest *C. lutescens* is adapted to dry soils. As an indicator it is obvious that only those trees which are adapted to alkaline and sometimes dry soils are likely to succeed.

The large shining yellow to yellowish-green patches, although flattened, have short ascending branches. The leaves are closely crowded, rather narrow and pointed, and are longitudinally furrowed. In conjunction with its chalk downland habitat and distinctive appearance, it is an easy plant to recognize. The allied *C. sericeum* which, however, grows on walls, rocks, and tree stumps can be confused with *C. lutescens*.

ACKNOWLEDGEMENTS

I am extremely grateful to Dr. E. V. Watson and to the Syndics of the Cambridge University Press for the illustrations given here which are reproduced from *British Mosses and Liverworts*. I am also indebted to Dr. Watson for a number of suggestions. The Appendix has been compiled from Watson, W., *The Bryophytes and Lichens of British Woods*, and is published by kind permission of the author and the publishers, Blackwell Scientific Publications.

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APPENDIX

Distribution in British Woodlands of the Species Described. (Journ. of Ecol. xxiv, nos. 1 and 2 (1936). W. Watson)

Species	*Q. sessil*	*Q. robur*	*Heathy oak*	*Birch*	*Conifer*	*Ash*	*Ash-Scrub*	*Ash-Oak*	*Alder*	*Beech*	*Oak-Beech*
Rhacomitrium lanuginosum	o	..	o–f	r	r	..	r	..	..	..	..
Leucobryum glaucum	f–a	o	a	f	f	vr	..	vr	..	..	o
Pleurozium schreberi	a	o–f	a	a	f–a	o	o	f	..	r	r
Hylocomium splendens	a	o	a	a	f–a	o	f	f	..	r–o	o
Polytrichum commune	la	l	l	lf	la	..	..	..	f	..	..
Plagiothecium undulatum	a	o	f	f	f–a	o	..	o	..	—	..
Campylopus flexuosus	f	o	a	f	f	vr	..	o	—	vr	o
Dicranum scoparium	a	f	a	a	a	a	a	f	o	o–a	o
Polytrichum piliferum	f	r	a	—	—	vr	r	r	..	..	..
Dicranella heteromalla	a	o–f	a	f–a	a	o	o	f	o	o	f
Polytrichum formosum	a	a	a	la	la	r	o	o	..	o	r
Mnium hornum	a–sd	o–f	a	f	o–f	a	a	a	f	f	a
Hypnum cupressiforme	a	a	a	f	a	a	a	a	f	a	a
Thuidium tamarascinum	a	a	a	f	f	a–sd	f	f–a	..	f	a
Pseudoschleropodium purum	a	o	a	a	a	o	o	a	f	o–f	f–a
Atrichum undulatum	sd	a	a	f	a	f	f	f–a	o	f	a
Rhytidiadelphus loreus	a	o	f	..	f	r	r	o	..	o	o
R. squarrosus	f	o–f	a	f	a	o	f	o	o	o	o
R. triquetrus	a	a	a	o	f	a	a	f–a	..	f	a
Cirriphyllum piliferum	o	a	—	—	—	o–f	o	o	r	o	f
Eurhynchium striatum	f–a	f	o–f	o	o	f–sd	f	a	o	f	a
E. praelongum	a	a–sd	f	f	o	a	a	a	f	o–f	a
Fissidens taxifolius	o	a	o	o	o	f	f	f	..	f	f–a
Mnium undulatum	a	a–sd	o	f	o	a	f	f–a	o	o–l	f
Camptothecium lutescens	..	r	..	..	..	o	f	r	..	o	r

KEY: a, abundant; f, frequent; o, occasional; r, rare; d, dominant; sd, sub dominant; l, local; —, not seen and presumably rare or absent.

YORKSHIRE EXCURSION

Hardwoods

THE Society met from the 26th to 30th September, 1960, with headquarters in Harrogate. Ninety-two enrolled and nearly one hundred attended. For many reasons this was a distinguished meeting. First, we were almost entirely concerned with hardwoods grown on private estates and with the reasons behind different owners policies and methods of management. Second, the Society was able to meet Lord Bolton, his son, and his forester, and to see for itself some of his very outstanding work on sycamore at Bolton Hall in Wensleydale and hear him explain his aims and ideas. Third, we were given a most instructive talk by Mr. A. J. Green the timber merchant on the prices he had paid for logs shown us and his reasons for paying them: an almost unique experience. Fourth, Mr. Dent included three new features in the excursion: a theme was selected for each day's outing: attention was drawn in the coaches to important things seen on the road: halts were carefully thought out and the discussion at each limited to the particular points just seen. Fifth, the excellently arranged series of colour slides all from members' photographs taken in the Ardennes and shown by Mr. Penistan on the first night. Sixth, serious consideration was given at the annual general meeting to a proposal to develop the Society as a professional body. Last, the weather was kind and the air wonderful!

The Society thanks all concerned and particularly Mr. Dent.

27th. *September, Bolton Hall.* Theme for the day, 'Growing hardwoods for profit'. The visitor from the south to the Pennines is at first surprised to find sycamore the dominant species both on the farmlands and in the woods. But it certainly is; and no one has put sycamore to better use than Lord Bolton. At Bolton Hall the object is to grow first-quality timber of large girth but not of great length. To grow it fast and always in mixture and always by groups. The main species used are sycamore, ash, and European larch. To secure the best prices, sycamore must have a breast height quarter girth of 20 inches and a clean butt length of 20 feet. This means pruning. It is hoped by the use of good strains and by heavy thinning from the start to reduce the rotation from 100 to 70 or 80 years. At present prices, even without an occasional 'curly grain' (a feature probably due to physical strains and stresses in the tree and only doubtfully hereditary), a handsome profit is obtained and it may well pay to replace some mediocre stands of other species with sycamore. A point of interest is the season selected for pruning sycamore. This arose from a question about the best season for pruning poplar to which the same argument applies. Sap rises earlier in sycamore than in most other trees and the spring is avoided for pruning. June is considered the best month or any time from then on until August when the tree is least likely to 'bleed'. We may add that one member considered that August was the best month to plant out nursery stock of sycamore for similar reasons.

28th. *September, Harewood House.* Theme for the day, 'Management and regeneration of landscape woodlands'. The Society was concerned here mainly with plans for the preservation of the sky-line. Proximity to Leeds and an evident awe of 'Capability' Brown is paralysing the management of the sky-line landscape woodlands. We must sympathize with the estate over the very sudden and disastrous wind which in 1956 blew down 10,000 trees including 300 to 400 of Brown's sky-line beech and it must be noted that this has already largely been made good. But what about the rest? The trees are nearly 200 years old on very exposed sites and, if Brown's work is not to be lost, a plan must be devised and carried through resolutely for their replacement. To do nothing is to court disaster and speed is essential.

29th. *September, Castle Howard Estate.* Theme for the day, 'Relative future prospects in private forestry of hardwoods and conifers on fertile sites'. At Coneysthorpe Banks a 200-acre wood with about 75 per cent. oak was to be clear-felled and replanted in 3 years with European larch, beech, sycamore, and ash. Two very interesting things were shown here by the agent Lord Morpeth. These were the decision to fell all the oak and the method of selling the trees. We quote below from the notes provided.

It was decided in 1959 that as the area was so under-stocked and increment so slow, a clear fall was the proper solution. The method adopted for selling the timber was perhaps unusual. It could have been sold in 50 acre blocks by tender, auction, or by agreement. The estate having made their valuation, approached Mr. A. J. Green, Timber Merchant, of Silsden. He and his father before him have dealt with the estate for over 30 years. After much discussion, no agreement on the valuation had been reached. It was then decided that felled measure was the best solution, and that the timber merchant should be given the whole 200 acres to work over. It was thought, and so it proved, that the timber merchant would have a much better chance to find his markets by giving him freedom to move about the area. The provision being that the first 60 acres should be cleared by the merchant ready for planting by the autumn of 1960, and that any rise in market prices should go to the estate. A new road was made to the centre of the wood which also served a farm. By allowing the timber merchant to fell all over the area considerable increases in prices have been obtained, and it would appear that the original valuation figure will be exceeded.

The decision to fell all the oak which was of very fair shape seemed on first sight rather shocking but it was demonstrated that they were very slow growing and shaken and there was no need to consider amenity in the area.

Mr. Green then demonstrated the prices that he had been able to offer by displaying 31 logs and pricing them. These prices were certainly markedly in advance of prices obtainable lately in the Midlands but the circumstances were admittedly a little unusual.

In the afternoon we saw Shaw Wood, 45 acres, which had been poorly stocked hardwood with scrubby gaps. In 1955 the worst trees were felled and groups of larch, beech, *Tsuga*, *Thuya*, &c., were planted. Not enough light had been let in so more trees were felled in 1958 and 1960. Members were asked to criticize but with thriving groups of adequate size before them could voice little but praise coupled with the hope that they would be kept growing fast by progressive

removal of the old trees. The absence of game probably explains why these groups were more flourishing than those seen in Cawdor Old Wood last year.

30th. *September* (*morning only*). On the way to Farnley Hall Estate the Society was given an idea of the diversity of woodland ownership in the Harrogate area.

At Farnley Hall where the theme for the day was 'the economics of small estate forestry' the Society was met by Major Horton-Fawkes and was shown round by him. Among the many good things that he had to say we may quote 'managing woodlands successfully requires mania, commonsense, and economics'; 'you must think bigger than the parish'; and (not to be taken too literally) 'don't engage more woodmen than you can employ fully on wet time'.

The excursion ended with a visit to the permanent show ground site of the Yorkshire Agricultural Society.

29th. *September* (*evening*). Discussion 'The future of hardwoods in British forestry'.

Mr. Langshaw Rowland, who opened the discussion, regarded the planting of hardwoods at the present time as an act of faith. Some assessment of their value was important as, while softwoods must provide the bulk of our future requirements, we were doing little to replace the hardwoods we were taking out, and might well be found short of them. A difficulty was that the markets for hardwoods depended to some extent on changing fashion. Sycamore was once regarded as a weed and only useful for faggots in the house. Elm used to be sold at a pound a tree. He remembered as a very young man suggesting that sycamore might one day be worth more than oak, a forecast considered ludicrous at that time but which has proved correct. In the same way he would venture to suggest that English elm in 25 years time might equal even walnut in value. He would advise owners of elms to keep them as an investment, and to grow more hedge-row elm and discourage the use of that fiendish implement the mechanical hedge cutter. Generally however, on account of uncertainty, the planting of hardwoods sounded uneconomic and he would suggest that the Forestry Commission set up a committee to consider the policy to be followed and, if there were found to be a case for maintaining hardwood timber supplies, to suggest the quantities needed and examine means of securing early returns as for instance by the provision of catch crops. He thought there might be a case for increased grants if hardwood planting is to be recommended.

Mr. Brownlie, speaking as a timber merchant, was optimistic for the future. Change was always going on just as we had changed since 1914 from horses to motor-vehicles. Timber was no longer used in the framework of aeroplanes. There was once a big market in India for sycamore for rollers for the jute trade and for beech for bobbins. All these had gone. After 1945, processed timber had tended to reduce the use of solid wood. Sixty years ago landowners were not interested in selling timber. He remembered his father turning to Ireland for supplies. Now, while demand was increasing, supplies were decreasing and much hardwood was imported from Africa and the Far East. He considered the markets for home grown hardwoods were so large we could never hope to meet them. The Forestry Commission had blundered in not trying to persuade woodland owners to plant

hardwoods for the market. Little was coming on and there would be a gap during which we should have to continue importing. There was a great future for *good* ash, oak, elm, sycamore, beech, and poplar: but he must emphasize that with rising costs, the quality must get higher and higher. It costs the same to cut a bad tree as a good one and at present we were able to sell only about 40 per cent. of the timber we pay for felling from the average forest.

Mr. Garfitt, who spoke as a timber grower rather than as a timber merchant, felt that there must be a good deal of guessing. He was encouraged, however, by Mr. Brownlie's view of the future. One form of demand may be sentimental and stem from increased interest in woodlands and desire to keep things as they were. Once hardwoods; always hardwoods. This may, however, be a minor matter compared with economics. Demands were for pulp and for veneer. The demands for high-quality veneer butts for the manufacture of articles of beauty will be as strong in 100 years time as it is today. Elm may also take its place as a decorative timber. Competitors are imported tropical hardwoods with no waste but rising standards of living in the tropics are likely to reduce the quantities available for export. As to growing hardwoods, he would grow in groups in a matrix of conifers. These help to draw up and clean the hardwood stems. A new form developed by him was isolated trees of useful hardwoods in a coppice of redwood giving a few magnificent hardwoods in a continuing underwood. Provided squirrels are kept down, he shared Mr. Brownlies' optimism.

The discussion then became general and the following took part. Messrs. Seymour, Harris, Galloway (J. A.), MacIver, MacGregor, Sweet, Dr. Wright, and Messrs. Martin, Grayson, Penistan, Wynne-Jones, Thom, and Wilson (P. J. O.). Points made were that there was too much haphazard planting and bad management and too little integration between growing and marketing. It was no use trying to grow hardwoods on slow growing sites when butts 30 inches quarter girth and above can be grown in 90 years in the right soils. Some suggestions were made for zoning by species but mainly to use soils to the best advantage, e.g. chalk for beech. In short, we must grow only finest quality timber and as fast as possible. Information about disease resisting varieties of elm[1] and the outlook for poplar would be appreciated.

General. Confining attention to hardwoods seriously limited the choice of the woodlands to be visited. The careful planning and choice of halts did something to improve the standard of discussion in the woods.

Time cut short the evening discussion but without considerable and lengthy investigation no definite recommendations could be recorded and rightly no attempt was made to summarize.

The meeting has called attention to uneasiness about the future place of hardwoods in British forestry and to the need for investigation and guidance.

[1] For progress made in this respect see T. R. Peace (1960): *The Status and Development of Elm Disease in Britain.* Forestry Commission Bulletin No. 33, H.M.S.O. 10*s.* net.

STUDIES ON *ULMUS*

IV. *The Village elms of Huntingdonshire and a new method for exploring taxonomic discontinuity*

R. H. RICHENS

(*Commonwealth Bureau of Plant Breeding and Genetics, Cambridge*)

SUMMARY

Further to studies of the elm floras of Cambridgeshire and Hertfordshire (*Forestry*, xxxi. 132 and xxxii. 138), a biometrical study was made of the leaves of the village elms of Huntingdonshire, utilizing 102 samples. Most of the samples could be placed in three closely related and one more remote group of *U. carpinifolia*. Sporadic samples of *U. procera* and putative hybrids of *U. carpinifolia* × *U. glabra* and *U. carpinifolia* × *U. procera* were also found.

It is thought probable that the most frequently occurring type of *U. carpinifolia* is of Roman introduction, Godmanchester being a likely centre of distribution. Most of the *U. procera* appears to date back no farther than the eighteenth century.

Some notes on the horticultural variety known as the Huntingdon Elm are included.

TWO county surveys describing the local elm floras have already been published (Richens, 1958, 1959). In this paper the elm flora of the villages of Huntingdonshire is described. Use is made, in the course of this account, of a new method for characterizing taxonomic discontinuity which could be applied also to other taxa. Historical evidence of elms in this area in earlier times is also assembled.

SAMPLING TECHNIQUE

The area investigated is the ancient county of Huntingdonshire, excluding the completely detached parish of Swineshead.

There are two main regions within the county. The greater part comprises a gently undulating landscape in which the soils are derived from clays, either Oxford clay or boulder clay. Towards the east there is a considerable area of fenland. There are also two minor regions: a Jurassic limestone outcrop in the extreme north, around Elton, and a small area of lower greensand around Everton in the extreme south of the county.

As in many low-lying regions, human settlement and the elms that are associated with it are largely dependent on the drainage system. Most of the county is in the basin of the Ouse which bisects the county into a larger north-western portion and a smaller south-eastern portion. The Nene forms the county boundary on the north.

The sampling technique is similar to that adopted in the previous two studies. One elm is sampled from the old closes around each ancient parish unless markedly dissimilar types are observed; in the latter case, each type is collected.

BIOMETRIC TECHNIQUE

The eight quantitative foliar characters previously used form the basis of the present investigation. These are: absolute length of the longer side of the lamina; lamina breadth/lamina length; petiole length/lamina length; the degree of basal asymmetry; the absolute number of teeth; and the breadth, length, and depth of the primary teeth (cf. Richens, 1958). Scabrous leaves are indicated by an asterisk.

The leaves sampled are subdistal members of dwarf shoots developed from large branches; five leaves per tree are measured.

RESULTS

The mean measurements of all the samples collected are presented in Table I. The measurements for each character are reduced to a 10-unit scale (0–9) as previously, the characters being treated in the order set out below.

The range and size of the scaled unit for each character are as follows:

Length	3–8 cm.,	1 unit being	0·5 cm.
Relative breadth	0·40–0·90,	" "	0·05
Relative petiole length	0·00–0·20,	" "	0·02
Basal asymmetry	0·00–0·20,	" "	0·02
Tooth number	50–150,	" "	10
Tooth breadth	3–8 mm.,	" "	0·5 mm.
Tooth length	3–8 mm.,	" "	0·5 mm.
Tooth depth	0–5 mm.,	" "	0·5 mm.

In the previous studies taxonomic groups were defined in terms of the lower and upper limits of each quantitative character, the distinctions being made to correspond as far as possible to natural discontinuities. However, discontinuity was treated intuitively rather than precisely, and in the present paper a method of treating discontinuity more exactly will be described.

Samples are designated by the name of their place of origin, multiple collections from one place being differentiated by superscripts. Taxonomic groups are written in capitals and named after a type sample.

Illustrations of representative leaves of the entire collection are given in Fig. 1. The areas of distribution of the taxonomic groups obtained below are shown in Fig. 2 and their biometrical limits in Table II. In Fig. 2.2 is shown the area in which elms are frequent. It will be noted that elms are abundant throughout the entire county with the exception of the fenland to the west, and some parishes in the extreme north. This situation appears little different from that obtaining in 1687 when Aubrey travelled from London to Durham. He observed no roadside elms north of Stamford but, between London and Stamford, elm in 'every hedge almost'.

DISCONTINUITY

The notion of continuous variation can hardly be applied to characters treated as qualitative. Since presence or absence of scabrosity is so treated here, it will be excluded from the following discussion. The other eight foliar characters are quantitative and can therefore be profitably used in an investigation of the discontinuity or otherwise of variation.

It is evident that taxonomic ($\mathcal{T}$) continuity is a complex concept and admits of various degrees and kinds. First of all, it is necessary to lay down the interval of comparison used. By this is meant the size of the difference in a biometrical character less than which signifies $\mathcal{T}$-continuity, and greater than which, $\mathcal{T}$-dis-

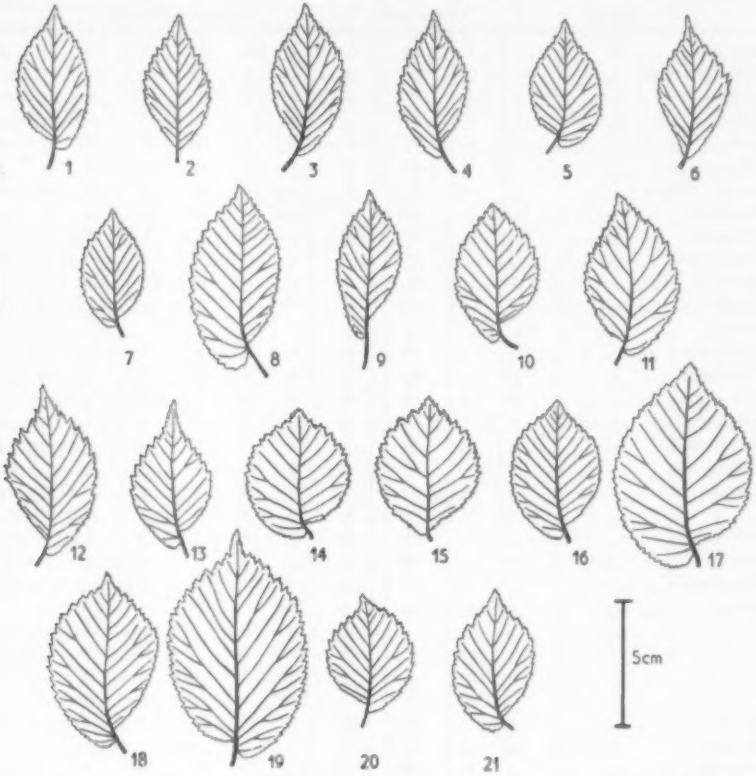

FIG. 1. Specimen elm leaves. 1, Houghton (GODMANCHESTER); 2, Chesterton; 3, Little Stukeley; 4, Wyton[a]; 5, Long Stow; 6, Kimbolton; 7, Great Gidding (GIDDING); 8, St. Neots[a] (ST. NEOTS); 9, Abbotsley; 10, Orton Longueville (ORTON); 11, Folksworth[b]; 12, Waresley; 13, Bluntisham; 14, Hartford[b] (*U. procera*); 15, Keyston[b] (*U. procera*); 16, Orton Waterville[b] (*U. glabra*); 17, Elton[c] (Dutch Elm); 18, Southoe[a] (putative *U. carpinifolia* × *U. glabra*); 19, Huntingdon Elm; 20, Wyton[b] (putative *U. carpinifolia* × *U. procera*); 21, Elton[b].

continuity. Thus, taking the relative breadth measurements for the Brampton, Lutton, Everton, and St. Neots[b] samples, 2, 1, 9, 8, respectively, and taking the interval of comparison as 1 (0·1 of the range), then the Brampton and Lutton samples show $\mathcal{T}$-continuity, so do the Everton and St. Neots[b] samples, but the two $\mathcal{T}$-continuous groups are $\mathcal{T}$-discontinuous with each other. $\mathcal{T}$-continuity between all four samples is only arrived at by raising the interval of comparison to 6.

TABLE I. *Mean scaled values for* (1) *length*, (2) *relative breadth*, (3) *relative petiole length*, (4) *basal asymmetry*, (5) *tooth number*, (6) *tooth breadth*, (7) *tooth length*, *and* (8) *tooth depth. Grid reference is to minor squares of major square 52.*

Parish		Grid reference	Biometrical values
Abbotsley		25	6 . 1 10 5 . 3 . 3 4 4
Abbot's Ripton		27	4 . 2 7 4 . 4 . 0 1 3
Alconbury		17	4 . 2 5 4 . 6 . 2 3 4
Alwalton			
Barham		17	6 . 2 5 4 . 6 . 2 3 4
Bluntisham		37	5 . 3 5 5 . 5 . 4 4 5
Botolphbridge		19	4 . 4 6 4 . 3 . 4 4 4
Brampton		27	5 . 2 6 4 . 3 . 2 3 4
Brington		07	5 . 2 6 4 . 6 . 2 3 4
Broughton		27	5 . 2 7 3 . 3 . 2 2 4
Buckden		16	2 . 5 5 4 . 3 . 1 2 3
Buckworth		17	4 . 2 5 4 . 5 . 1 2 4
Bury			
Caldecote		18	4 . 2 5 2 . 5 . 3 4 5
Catworth		07	5 . 4 6 5 . 3 . 3 4 5
Chesterton		19	4 . 2 5 2 . 5 . 1 2 4
Conington		18	5 . 1 7 1 . 4 . 4 5 6
Coppinford		18	5 . 2 6 3 . 5 . 3 4 4
Covington		07	5 . 3 8 4 . 5 . 3 3 5
Denton	*a*	18	4 . 2 8 4 . 5 . 3 4 5
	b		4 . 1 5 3 . 6 . 2 3 4
Diddington		16	3 . 3 8 5 . 3 . 1 1 3
Easton		17	7 . 3 5 3 . 4 . 5 5 4
Ellington		17	5 . 2 6 6 . 6 . 3 5 5
Elton	*a*	09	4 . 2 4 3 . 3 . 2 3 4
	b		4 . 4 3 3 . 3 . 5 5 5*
	c		8 . 7 4 5 . 6 . 8 7 6
	d		4 . 8 6 5 . 3 . 4 4 5*
	e		6 . 1 6 2 . 6 . 2 3 5
Everton		25	4 . 9 4 7 . 3 . 6 5 7*
Farcet			
Fen Stanton	*a*	36	6 . 4 7 6 . 4 . 3 4 4
	b		4 . 7 5 6 . 4 . 4 4 4*
Folksworth	*a*	18	5 . 2 8 4 . 4 . 3 3 4
	b		6 . 4 5 5 . 8 . 4 4 4
Glatton		18	6 . 1 6 2 . 8 . 3 4 6
Godmanchester		27	4 . 2 5 3 . 4 . 2 2 4
Grafham		16	5 . 2 6 3 . 5 . 2 3 5
Great Gidding		18	3 . 3 6 3 . 4 . 2 2 4
Great Gransden		25	4 . 2 8 5 . 2 . 3 4 4
Great Paxton		26	5 . 3 10 6 . 4 . 3 4 5
Great Staughton		16	4 . 3 6 2 . 3 . 2 2 4
Great Stukeley		27	5 . 1 6 3 . 3 . 3 5 5
Haddon		19	5 . 1 8 2 . 7 . 2 2 4
Hamerton		17	5 . 2 6 3 . 4 . 2 4 4
Hartford	*a*	27	5 . 3 6 4 . 7 . 2 3 4
	b		4 . 8 3 5 . 3 . 5 5 5*

TABLE I (*cont.*)

Parish		*Grid reference*	*Biometrical values*								
Hemingford Abbots		27	5	1	8	4	5	1	2	3
Hemingford Grey	*a*	27	6	3	8	6	4	1	1	3
	b		5	0	9	5	6	0	0	3
Holywell		37	5	2	6	4	5	1	2	3
Houghton		27	5	2	7	3	5	2	3	3
Huntingdon	*a*	27	5	0	7	2	2	4	5	4
	b		6	2	7	6	8	1	2	3
	c		6	0	5	2	5	2	4	4
Keyston	*a*	07	4	2	5	2	1	2	3	3
	b		4	8	2	3	1	5	5	6*
Kimbolton		06	4	2	4	1	3	2	3	4
King's Ripton		27	3	2	6	2	5	1	2	3
Leighton Bromswold		17	5	2	6	3	5	2	3	4
Little Gidding		18	3	2	3	3	4	0	1	4
Little Raveley		27	4	2	6	3	5	0	2	3
Little Stukeley		27	6	3	7	4	5	2	3	4
Long Stow		17	4	4	7	5	4	1	2	3
Luddington in the Brook		18	5	1	8	4	6	2	3	3
Lutton		18	5	1	5	3	6	3	4	4
Molesworth		07	5	2	7	4	5	2	3	4
Morborne		19	4	1	7	4	7	1	2	4
Offord Cluny		26	4	2	7	4	4	3	4	4
Offord Darcy		26	4	1	4	3	4	1	2	4
Old Weston		07	3	2	9	4	4	1	2	4
Orton Longueville		19	4	5	6	6	2	5	5	4
Orton Waterville	*a*	19	4	1	5	2	5	1	2	4
	b		4	5	4	4	7	1	2	4*
Papworth St. Agnes		26	5	3	6	3	4	2	3	4
Ramsey		28	4	3	6	2	2	3	3	3
St. Ives	*a*	37	4	3	7	4	5	1	2	4
	b		4	8	5	8	3	5	5	6*
St. Neots	*a*	16	6	3	9	6	4	3	3	4
(including Eynesbury)	*b*		4	8	4	5	3	5	5	6*
Sawtry	*a*	18	5	2	8	4	6	2	3	4
	b		4	4	6	5	4	6	6	6
Somersham	*a*	37	6	2	6	4	8	1	2	4
	b		8	2	5	3	3	4	5	4
Southoe	*a*	16	6	5	6	4	6	2	2	4
	b		3	3	10	6	3	1	2	4
Spaldwick		17	5	2	7	4	7	2	3	4
Stanground										
Steeple Gidding		18	2	3	5	4	3	1	2	4
Stibbington										
Stilton		18	5	1	6	3	4	3	4	4
Thurning		08	3	3	8	2	3	1	1	4
Upton	*a*	17	4	2	7	4	4	3	3	3
	b		6	3	9	5	5	2	3	3
Warboys		38	5	1	5	4	5	1	2	3
Waresley		25	7	2	4	4	8	4	5	5

TABLE I (*cont.*)

Parish		Grid reference	Biometrical values
Washingley		18	3 . 2 6 3 . 4 . 1 3 4
Water Newton		19	3 . 2 6 2 . 4 . 2 3 4
Winwick		18	4 . 3 9 6 . 2 . 3 3 5
Wistow		28	5 . 2 8 5 . 5 . 2 3 3
Woodstone			
Wood Walton		28	4 . 1 6 3 . 5 . 2 3 3
Woolley		17	5 . 2 6 3 . 7 . 1 2 3
Wyton.	*a*	27	5 . 2 8 5 . 6 . 2 3 4
	b		3 . 6 6 3 . 3 . 2 3 5
	c		4 . 3 7 2 . 2 . 2 3 5
Yaxley.		19	3 . 2 7 5 . 3 . 1 1 3
Yelling		26	5 . 2 5 2 . 3 . 2 3 4

TABLE II. *Taxonomic groups and their biometrical ranges*

Group	Biometrical range
GODMANCHESTER	4–5 . 1–3 5–8 2–4 . 3–7 . 0–3 2–4 3–5
GIDDING	2–3 . 2–3 5–9 2–4 . 3–4 . 0–2 1–3 4
ST. NEOTS	3–6 . 1–3 9–10 5–6 . 3–4 . 3 3–4 4–5
ORTON	4 . 4–5 6 4–6 . 2–4 . 4–6 4–6 4–6

The particular interval of comparison chosen obviously depends on the purpose of the study. A large interval may be appropriate to intergeneric comparisons; a small interval befits an investigation of intraspecific variation.

For present purposes, the interval of comparison is taken as 1 (0·1 of the range) for each of the eight characters studied so that two samples are regarded as $\mathcal{T}$-continuous should they differ by no more than 1 in any character. Thus, taking the following elms:

Brampton	5 . 2	6	4 . 3 . 2	3	4
Offord Cluny	4 . 2	7	4 . 4 . 3	4	4
Folksworth[a]	5 . 2	8	4 . 4 . 3	3	4,

Brampton and Offord Cluny, and Offord Cluny and Folksworth[a] are $\mathcal{T}$-continuous, while Brampton and Folksworth[a] are not, considered alone, but enter into a $\mathcal{T}$-continuous relation if Offord Cluny is included too. It is therefore necessary to distinguish between direct and indirect $\mathcal{T}$-continuity. Brampton is in direct $\mathcal{T}$-continuity with Offord Cluny and in indirect $\mathcal{T}$-continuity with Folksworth[a].

In the present treatment the same value (0·1 of the range) is taken as the interval of comparison for all characters. This is obviously the simplest course to pursue, but it is conceivable that, for a particular purpose, different intervals of comparisons could be used for different characters.

A statistician would doubtless prefer that the comparative crudity of this approach be refined by preliminary scale transformation to normalize the frequency distribution of each character (markedly skew for tooth number) and use

of standard-deviation units instead of range aliquots for the interval of comparison. The extra trouble involved in so doing may be justified in some cases; it appears unnecessary in what is essentially an exploratory technique.

So far, continuity has been treated as a purely taxonomic concept. However, it is useful, in the majority of cases, to study T-continuity in conjunction with geographical (G) continuity. There are cases, for instance, the distribution of cultivated wheat varieties, where geographical distribution may throw little light on the origins of the varieties concerned, even though it may throw considerable light on other matters. This is probably exceptional, however, and in most taxonomic studies, even of plants in which man is an important agent of distribution, geographical distribution yields information otherwise unobtainable.

Again, it is necessary to distinguish between various kinds of G-continuity. What may be termed absolute continuity, organic continuity between the different parts of a vegetatively reproducing plant, is the least likely to be encountered, though it is of significance in local studies of populations of *Ulmus carpinifolia* Gled. which spreads by suckering. This type of G-continuity is not considered further.

On the analogy of the treatment of T-continuity, a concept of G-continuity can be derived by dividing the area studied into a grid of squares, and taking as G-continuous any samples from squares touching by their edges or corners. This gives eight G-continuities to each square just as two biometrical characters have eight possible T-continuities. The interval of comparison is then determined by the size of the squares of the geographical grid.

Since, however, in a study covering an extensive area, it would probably be quite unfeasible to survey the entire ground area, it is possible to establish sampling areas, arranged again in a rectangular grid, the interval of comparison being determined by the distance between the sample areas.

And lastly, there may be cases, as in the present study, where a rectangular grid is inappropriate, since the potential sites of village elms are villages which are not arranged in anything approaching a rectangular grid. It is possible in this case to take the environs of each village as the sampling area and to maintain the principle of eight G-continuities as follows. The region around each sampling area (village) is divided into eight sectors, by drawing lines approximately N.–S., E.–W., NE.–SW., and NW.–SE. through the sample area. Then, the sampling area is joined by a line to the nearest sampling area in each sector and so on for all the other sampling areas. As a result, a grid is obtained, some points having more than eight connexions, but none less. It is well to bear in mind that apparent barriers to dispersal, for instance the Bristol Channel between Wales and Cornwall, or the English Channel between Kent and France, may be of no consequence as far as distribution by human agency is concerned. By the method outlined, the absolute distance between the sampling points no longer provides the interval of comparisons, which has now to be described in terms of the nature of the sampling areas, in this case ancient parishes.

As before, G-continuity can be direct or indirect. On a spheroid such as the earth, all sampling points will be in indirect G-continuity.

Having stated what is to be understood by *G*-continuity, it is possible to combine the two notions of continuity into one of taxonomic-geographic (*TG*) continuity. Two samples are regarded as in direct *TG*-continuity if they are both in direct *T*-continuity and in direct *G*-continuity. Samples connected by intermediaries in direct *TG*-continuity are in indirect *TG*-continuity.

A more formal treatment of continuity is given in the appendix. With these explanations, it is now possible to analyse the Huntingdonshire elm collection in relatively precise terms.

TAXONOMIC ANALYSIS

In Fig. 2.1 all the samples collected in the county are plotted, all those in direct *TG*-continuity being connected by bars. The number of Huntingdonshire populations of samples in indirect *TG*-continuity *inter se* is ten and of these, seven, those labelled ABCEFGI, overlap in the range of their biometrical characters, and all their members, excepting a few extreme deviants, come into a taxonomic group of biometrical range:

4–5 . 1–3 5–8 2–4 . 3–7 . 0–3 2–4 3–5.

This population, the characteristic type for the county, will be termed the GODMANCHESTER group.

Population D, together with some related elms in the same area, is characterized by the range:

2–3 . 2–3 5–9 2–4 . 3–4 . 0–2 1–3 4.

It will be named the GIDDING group.

The two samples of population H are best treated as deviants of the GODMANCHESTER group with which they are in *T*-continuity. Population J, together with the nearby Abbotsley and Southoe[b] elms is characterized by the biometrical range:

3–6 . 1–3 9–10 5–6 . 3–4 . 1–3 2–4 4–5.

It will be designated the ST. NEOTS group.

One other group can usefully be recognized though its members, the Botolphbridge, Orton Longueville, and Sawtry[b] elms, are not in *TG*-continuity. The range of this group, designated ORTON, is:

4 . 4–5 6 4–6 . 2–4 . 4–6 4–6 4–6.

All the above groups can be accommodated in *U. carpinifolia* Gled. sensu Rehder.

Sharply distinguished from the foregoing by their biometrical characters but very heterogeneous *inter se* are seven representatives of *U. procera* Salisb. In view of this heterogeneity and their scattered distribution, they are not allocated to a group of their own.

The characteristics of the above groups will now be considered in more detail.

GODMANCHESTER. This group is found throughout the entire county except in the extreme south. Its members are: Abbot's Ripton, Alconbury, Brington, Broughton, Buckworth, Caldecote, Chesterton, Coppingford, Covington,

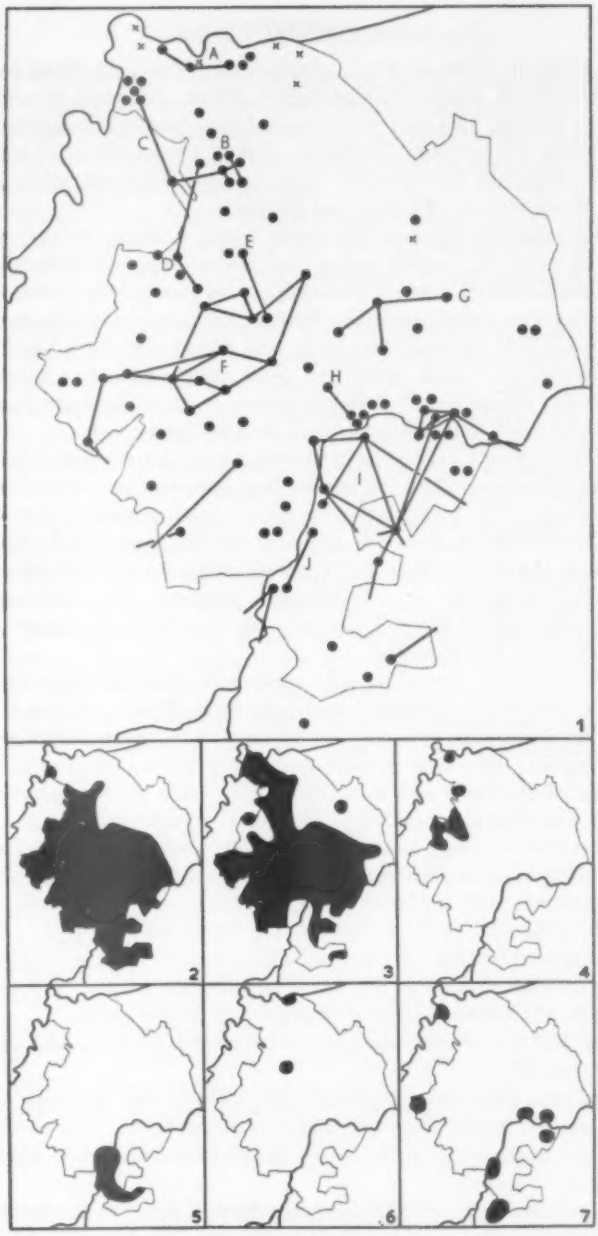

FIG. 2. Distribution maps. 1, Elm samples plotted to indicate *TG*-continuity; all samples connected by bars are in direct *TG*-continuity; sample areas from which no elms were obtained are indicated by crosses; 2, areas in which elms are frequent; 3, GODMANCHESTER; 4, GIDDING; 5, ST. NEOTS; 6, ORTON; 7, *U. procera*. The river to the north is the Nene; that to the south is the Ouse.

Denton[a], Denton[b], Folksworth[a], Godmanchester, Grafham, Great Staughton, Haddon, Hamerton, Hartford[a], Hemingford Abbots, Holywell, Houghton (Fig. 1.1), King's Ripton, Leighton Bromswold, Little Raveley, Luddington in the Brook, Lutton, Molesworth, Morborne, Offord Cluny, Offord Darcy, Orton Waterville[a], Papworth St. Agnes, St. Ives[a], Sawtry[a], Spaldwick, Stilton, Upton[a], Warboys, Wood Walton, Woolley, and Yelling.

The salient characteristics are the narrow leaves, moderate to low asymmetry, and smallish teeth. It is worth noting that low asymmetry is especially characteristic of the elms in the north of the county, as for example Chesterton (Fig. 1.2).

Many other elms differ but slightly from typical members of this group. Thus, the Barham, Little Stukeley (Fig. 1.3), and Elton[e] elms have slightly longer leaves; Somersham[a] longer leaves and more numerous teeth; King's Ripton slightly shorter leaves; Elton[a] a slightly shorter petiole; Keyston[a], Ramsey, and Wyton[c] lower tooth numbers; and Great Stukeley larger teeth.

Special interest attaches to the elms whose leaves have a higher basal asymmetry than typical since these are intermediate between the GODMANCHESTER and ST. NEOTS groups. The tendency towards greater basal asymmetry is generally but sporadically distributed, though it only achieves full expression in the ST. NEOTS elms towards the Bedfordshire and Cambridgeshire borders. Samples with increased basal asymmetry are: Diddington, Ellington, Fen Stanton[a], Great Gransden, Hemingford Grey (both samples), Huntingdon[b], Upton[b], Wistow, Wyton[a] (Fig. 1.4), and Yaxley.

Increase in relative breadth is only occasionally encountered, namely in the Buckden, Catworth, Fen Stanton[a], and Long Stow (Fig. 1.5) samples.

Of the remaining elms with manifest affinities to this group, the Huntingdon[a] and Huntingdon[c] elms differ in their very narrow leaves; the Glatton specimen has unusually large leaves with many deep teeth; while the Kimbolton elm (Fig. 1.6) has an unusually short petiole and low basal asymmetry.

Deviating more strongly from the typical leaf configuration, the Easton elm is considerably larger and has much coarser teeth than the norm for this group. The Conington elm also has coarse teeth and an unusually symmetrical leaf base.

GIDDING. This small group comprises the Great Gidding (Fig. 1.7), Little Gidding, Steeple Gidding, Old Weston, Thurning, and Washingley elms, which occupy a compact area near the Northamptonshire border, and the Water Newton elm, an extreme variant of population A farther north.

It is very similar to the preceding group but has smaller leaves and, on average, fewer and finer teeth.

ST. NEOTS. The four elms comprising this group are the Abbotsley (Fig. 1.9), Great Paxton, St. Neots[a] (Fig. 1.8), and Southoe[b] samples. They all come from a limited area in the south of the county in the Ouse valley or its tributary the Hen Brook.

The characters that distinguish these elms from all others in the county are the high values for petiole length and basal asymmetry. The Winwick elm is similar but has fewer teeth.

ORTON. Like the preceding two groups, this assemblage is also small, comprising

the Botolphbridge, Orton Longueville (Fig. 1.10), and Sawtry[b] elms. The area of distribution appears to be restricted to the north of the county.

The distinguishing characteristics are the moderately broad leaves and coarse teeth. The Folksworth[b] (Fig. 1.11) sample appears to be related, but differs in its large leaf size and higher tooth number.

Of the forms of *U. carpinifolia* not yet mentioned, the Waresley elm (Fig. 1.12) is a large coarsely toothed elm of a type found in northern Bedfordshire; the Bluntisham (Fig. 1.13) and Somersham[b] species are coarsely toothed elms from the fen border.

It has already been noted that the samples representing *U. procera* are too heterogeneous to be treated as a biometrically well-defined group. They comprise the Elton[d], Everton, Fen Stanton[b], Hartford[b] (Fig. 1.14), Keyston[b] (Fig. 1.15), St. Ives[b], and St. Neots[b] elms. The distribution is very scattered, but three main zones can be distinguished: (1) the Ouse valley, (2) the greensand outcrop in the extreme south, represented by the Everton sample, which is contiguous with the sparse *U. procera* population of eastern Bedfordshire, and (3) the extreme west, represented by Keyston[b], contiguous with the *U. procera* population of the Nene valley in Northamptonshire.

U. glabra Huds. was encountered once only, the Orton Waterville[b] sample (Fig. 1.16). The Dutch Elm was also found once only, namely Elton[c] (Fig. 1.17).

Two of the samples, Southoe[a] (Fig. 1.18) and Wyton[b] (Fig. 1.19), appear to be hybrids between different species of elm. The Southoe[a] sample is intermediate biometrically between the local type of *U. carpinifolia*, as represented by Southoe[b], and *U. glabra* as it occurs in the adjoining county of Bedfordshire, for instance at Sharnbrook. The comparative biometrical data for these three elms are:

Southoe[b]	.	.	3	.	3	10	6	.	3	.	1	2	4
Southoe[a]	.	.	6	.	5	6	4	.	6	.	2	2	4
Sharnbrook	.	.	9	.	5	2	4	.	9	.	3	3	5*

The Southoe[a] elm, like the putative *U. carpinifolia* × *U. glabra* hybrid described for Hertfordshire (Richens, 1959) is smooth-leaved. It should be mentioned, however, that most of the samples of *U. glabra* collected in Bedfordshire (Richens, unpublished survey) have leaves of smaller relative breadth than the Southoe[a] sample. This does not, however, preclude their being regarded as possible parental types since, on transforming the scale of measurement of breadth from the relative scale used here to the absolute breadth, the Southoe[a] elm is intermediate. Thus, comparing the Southoe[a] elm with a rather narrow-leaved *U. glabra* specimen from Husborne Crawley, Bedfordshire, the latter is narrower on a relative scale but broader on an absolute scale. Thus:

	Southoe[a]	*Husborne Crawley*
Relative breadth (unscaled) .	0·66	0·59
Relative breadth (on 0–9 scale) .	5	3
Absolute breadth . . .	4·2 cm.	4·8 cm.

While considering putative hybridization between *U. carpinifolia* and *U. glabra*, mention should be made of an elm not encountered in the survey proper, the horticultural clone known as the Huntingdon Elm. This elm is frequent in nineteenth-century plantings, especially in parks and in towns, but since it only arose as a seedling in the mid-eighteenth century, it is naturally unrepresented in the older elm flora. The biometrical characterization of a typical sample (Fig. 1.19) of this clone growing in Hinchingbrook Park, Huntingdon, its place of origin, is:

10 . 5 3 3 . 7 . 4 5 6.

The characteristics indicative of *U. glabra* are the high absolute length, moderate relative breadth, and high tooth number; the smoothness of the leaf recalls *U. carpinifolia*; petiole length is intermediate between the norms for local populations of these two species. The distance of the seed cavity from the samara notch is also intermediate between that in the two putative parents.

Tooth size, however, is considerably greater than in local populations of either species and may be a manifestation of heterosis. It should be borne in mind, however, that *U. glabra* is far from its climatic optimum in this region. In the Scottish highlands, tooth size in *U. glabra* may considerably exceed that quoted here for the Huntingdon elm. It is conceivable that the Huntingdon elm is heterotic in southern England but not in Scotland. Cases of heterosis depending on environmental conditions are known in other organisms (cf. Dobzhansky and Spassky, 1954).

The Wyton[b] elm (Fig. 1.20) is intermediate biometrically between *U. carpinifolia* and *U. procera*, both of which occur along this stretch of the Ouse. It may be compared with two nearby samples, the Houghton elm (Fig. 1.1), a typical representative of the GODMANCHESTER group, and Hartford[b] (Fig. 1.14), a local specimen of *U. procera*.

Houghton	.	.	5	.	2	7	3	.	5	.	2	3	3
Wyton[b]	.	.	3	.	6	6	3	.	3	.	2	3	5
Hartford[b]	.	.	4	.	8	3	5	.	3	.	5	5	5*

It can be seen that Wyton[b] is intermediate between the other samples except that its leaves are slightly shorter than in either. In particular, it combines the broad leaves and deep teeth of *U. procera* with the smoothness, longer petiole and lower basal asymmetry of the Houghton sample. Only one tree of this type was observed and it may well be a hybrid between the two species. Evidence that these two species have hybridized in Cambridgeshire has already been presented (Richens, 1958).

The scabrous-leaved sample Elton[b] (Fig. 1.21) cannot be placed at present. It might, in view of the wide range of elms at Elton, be a hybrid segregate.

Compared with the elm flora of Cambridgeshire and Hertfordshire already described, that of Huntingdonshire is remarkably uniform, the GODMANCHESTER group of *U. carpinifolia* occupying the whole county except for the fens and the extreme south. This group is in *TG*-continuity with the BOXWORTH group of Cambridgeshire (Richens, 1958), the only difference being that the GODMANCHESTER group includes some elms with higher tooth numbers than encountered

in the Cambridgeshire group. The geographical limits of the GODMANCHESTER–BOXWORTH elms can now be fairly precisely stated. Later (unpublished) surveys have shown that elms of this type occur in a narrow band across northern Bedfordshire in *TG*-continuity with those of south-western Huntingdonshire. They probably do not penetrate into the Rockingham Forest area in Northamptonshire nor beyond the Nene valley to the north. They are absent from most of the fenland settlements except some of the southern parishes of the island of Ely. In Cambridgeshire they characterize the boulder-clay plateau in the west of the county but do not cross the Cam.

Both the GIDDING and ST. NEOTS groups appear to be derivatives of the GODMANCHESTER group with which they are in *T*-continuity. The former, localized in a small area towards the western bounds of the county, differs from the GODMANCHESTER group only in its smaller leaf dimensions. The ST. NEOTS group, restricted to the Ouse valley and Hen Brook, differs in its larger petioles and marked basal asymmetry, but, as already indicated, tendencies towards these conditions occur sporadically in elms closely related to those of the GODMANCHESTER group all over the county. The ST. NEOTS group is represented in western Cambridgeshire by the ELTISLEY group which occupies an area in direct extension of that of the ST. NEOTS group from which it has every appearance of being derived.

Elms resembling those of the ORTON group have not been encountered before and it appears advisable to postpone consideration of these till the elm flora to the north and north-east of the county has been examined.

HISTORICAL ANALYSIS

Although there is every reason for supposing that elm, presumably *U. glabra*, was present in the mixed forest that covered Huntingdonshire in late Boreal and succeeding epochs (cf. Godwin and Clifford, 1938), no evidence has been obtained that this species has persisted in the wild state in the county till recent times. This is in contrast with the situation in Bedfordshire where *U. glabra* still occurs wild and is well-attested historically from medieval times onwards. Druce (1926), in this treatment of the Huntingdonshire flora also doubts whether *U. glabra* occurs anywhere in the county except where planted. It is not a characteristic species of existing woodland; it is not mentioned in the description of primeval woodland (ash and alder) preceding the foundation of Ramsey Abbey in the Ramsey Chronicle; nor in the various descriptions of woodland in the Ramsey Chartulary (oak at Warboys and St. Ives, oak and ash at Little Stukeley and Wistow); nor in the numerous early nineteenth-century sales of timber from Brampton and Little Raveley woods (Hinchingbrooke Papers).

Failing any evidence of elm timber or charcoal remains from Romano-British times, the next line of evidence is provided by place-names. But, of the place-names treated in the relevant publication of the English Place-Name Society (Mawer and Stenton, 1926), only one, Lymage in Great Staughton parish, is even conjecturally connected with elm. Two alternative etymologies for this name are suggested, one based on Anglian *hlimme*, a torrent, which is unlikely on topographical grounds, and the other based on Celtic *lem*, meaning elm. Here again,

it cannot be said that the site provides any strong confirmation of the second suggestion. Elms are not frequent around Lymage Farm though they occur in some abundance in the villages around. Possibly the name had a wider application in earlier times, but all that can be safely inferred is that the name is consistent with the hypothesis that elm was present in this area in late pre-Anglian days but does not confirm it.

No place-names based on Old English *elm* or *wice* are recorded in the Place-Name Society's publication. The absence of names based on *elm* is not surprising since the local term in the county for any elm is *wych*, usually pronounced with a long *i* (Tebbutt, personal communication). This term is attested in local use from the fourteenth century onwards; it was, till recently, also in local use in Cambridgeshire and the related term *witchen* is found in Northamptonshire.

It is surprising, however, that no place-names based on *wice* are recorded in view of the undoubted presence of elm in the county in medieval times. It is just possible, however, that the parochial name Wyton (Wictun in the thirteenth century) is based on *wice* (or *wic*) meaning elm rather than on the etymologically unrelated *wic*, which most frequently denotes a livestock farm. Ekwall (1947) points out that it is difficult to distinguish between these two words when acting as initial elements of place-names; for while the palatal *c* in *wice* (or *wic*) meaning elm normally becomes *ch* in Middle English, it appears sometimes to become *k*, as in Weekley in Northamptonshire and perhaps Wickford in Essex (cf. Ekwall, 1947). The second term is adopted to account for Wyton in the Place-Name Society's publication though it is conceded that its significance in combination with *ton* is obscure. If, however, the first term is adopted, a semantically congruent combination is achieved analogous with Witcham and Witchford in the Isle of Ely, agreed by both Reaney (1943) and Ekwall (1947) to be based on *wice*, meaning elm.

However, it is clear that no certainty is attainable and that the present evidence from Huntingdonshire place-names must be regarded as inconclusive, both positively and negatively. Yet is it perhaps reasonable to argue that the failure of the typical elm of the island of Ely, presumably present at the time of the Domesday Survey in which Witcham and Witchford are mentioned, to extend into Huntingdonshire suggests that elms were already established there.

Coming now to more direct evidence, the earliest allusion that has been discovered so far concerns Elton, in the extreme north-west of the county, where it is stated in the Elton Court Rolls for 1331 (Ratcliff, 1946), that 'Johannes Abovebrok' succidit tres wiches stantes circa Crucem in le Overtoun'. Another Elton document, the account book of Sir Thomas Proby, provides evidence for the presence of elm at Yaxley, on the edge of the fens, in 1668, where Carpenter Wise is entered as 'felling wiches'. The driving of three large 'witch piles' into Whittlesey Mere in 1559 to mark a disputed boundary is recorded in a note appended to Bodger's (1786) map of the mere.

In the south of the county, the Parliamentary Survey of Brampton confirms

the presence of elm in this parish in 1650 when it alludes to 'the tymber trees of elme and ash now standinge within the said Warrens Cloase'.

All these references presumably refer to *U. carpinifolia* of or related to the GODMANCHESTER group. The presence of 'some okes and elmes growing in hedgerowes about the several closes' at Keyston in the extreme west of the county is recorded in 1589 (Hollings, 1936) but in this case it is not possible to say whether *U. carpinifolia* or *U. glabra* is involved. The widespread distribution of hedgerow elms by the early nineteenth century is recorded in detail by Parkinson (1811), who makes specific mention of elm in forty-two parishes.

Taking all the evidence into consideration, it seems highly probable that the GODMANCHESTER group of *U. carpinifolia* is of ancient introduction and had attained something like its present limits of distribution by the fourteenth century at the latest. Assuming the group had arrived prior to the Norman Conquest, it seems difficult to suggest any other period for its introduction than the Roman occupation, or, less likely, the short preceding Belgic phase. As suggested earlier (Richens, 1955), the probable reason for its introduction would have been to supply fodder.

The principal Roman sites in Huntingdonshire are the Ouse and Nene valleys. The latter seems to have an industrial region largely devoted to pottery; elms are infrequent in this zone and it is thought unlikely, from present evidence, that the Nene valley was a centre of distribution. The Ouse valley is a different matter. Godmanchester is on the site of a Roman town at the crossing of the Ouse by the Ermine Street. Roman settlement appears to have extended a considerable distance along the Ouse from this point. This zone of settlement occupies a central situation in the total area of distribution of the GODMANCHESTER group and it is thought that Godmanchester provides the most likely place to locate an introduction. From here, elms of the GODMANCHESTER type would have later spread over the entire county, except the fens, presumably by Anglian or Anglicized settlers, and thence into northern Bedfordshire and western Cambridgeshire. The inference that western Cambridgeshire received its elms from Huntingdonshire is interesting in that it accords with Gray's (1908) hypothesis of a dual origin of Anglian settlement in Cambridgeshire, Middle Anglian from the west and East Anglian from the east.

It is not possible yet to suggest whence the GODMANCHESTER elms came. Direct importation from the continent seems unlikely and this type of elm does not occur around London or in Kent. East Anglia or Essex seem the most probable sources, and are also likely areas into which continental elms may have been introduced. As already mentioned, the GIDDING and ST. NEOTS groups appear to be derivatives of the GODMANCHESTER type. It would be premature to discuss the origin of the ORTON and other *U. carpinifolia* types.

With regard to *U. procera*, no evidence has been obtained so far that this species is of ancient origin in the county generally. It is possible that it occurred anciently at Keyston, in the extreme west of the county, since this location is contiguous with the *U. procera* population of the middle Nene valley. It is possible, too, that *U. procera* was introduced early at Everton in the extreme south of the

county since this parish adjoins the sparse *U. procera* population of eastern Bedfordshire. But since, as will be mentioned shortly, it is known to have been planted at Everton in the eighteenth century, its status there is doubtful.

The Elton[d] sample is doubtless due to the extensive planting activities of the Proby family, lords of the manor of Elton, to whom can also be safely attributed the local stands of Dutch Elm, Elton[c].

The various *U. procera* samples of the Ouse valley are probably mostly products of Wood and Ingram's (now Laxton Bros.') nursery at Brampton. There is fortunately extant a day book of orders taken by J. Wood, of this firm, covering the period 1762–81. There are many references to large deliveries of elms to local estates. These are referred to in the earlier years as 'wiches'; later the entries are 'elms', sometimes qualified as 'Inglesh', 'brood lefd' or 'Duch'. Apparently, in this period, the firm was supplying the local form of *U. carpinifolia*, as in the Wimpole Avenue in Cambridgeshire, *U. procera* and the Dutch elm. The major consignments were to Brampton, Buckden, Diddington, Ellington, Everton, Fen Stanton, Godmanchester, Huntingdon (Hinchingbrook Park), St. Neots, and Spaldwick. There is therefore every likelihood that samples Everton and Fen Stanton[b] at least and the other Ouse valley samples too are eighteenth century introductions from this nursery. The status of the St. Neots[b] sample is less certain since this is in *TG*-continuity with the *U. procera* population of northern Bedfordshire which appears to reach its north-eastern limits at St. Neots. It is possible that here *U. procera* is both of early occurrence and later introduction.

Finally, the origin of the horticultural Huntingdon Elm remains to be considered. This variety was also introduced by the firm of Wood and Ingram and its origin is described by Ingram (1847). It was, he stated in 1847, raised upwards of a hundred years earlier from seed gathered from a tree in Hinchingbrook Park, Huntingdon, still in existence when he wrote and described as a 'true English or Field Elm (*Ulmus campestris*)'. The elms in and around Hinchingbrook Park today include *U. carpinifolia*, *U. procera*, and the Huntingdon Elm, as was the case when Elwes and Henry (1913) investigated this problem. Ingram's description of the mother tree could apply to either *U. carpinifolia* or *U. procera*, but since no characters of the Huntingdon Elm recall *U. procera* and since the probabilities are against mature trees of *U. procera* being present at Hinchingbrook Park as early as the mid-eighteenth century, it is highly probable, as Henry supposed, that the mother tree was *U. carpinifolia*.

The present study does not throw much further light on this matter, but the existence of another putative hybrid between *U. carpinifolia* and *U. glabra*, Southoe[a], suggests that circumstances favourable to interspecific hybridization have occasionally occurred in the Ouse valley. The chief problem is the location of a pollen source. *U. glabra* is rare in the county and occurs only as isolated trees, some possibly originating from stocks on which *U. procera* had been grafted. *U. glabra*, however, does occur in quantity in a wild state and planted in Bedfordshire. It is therefore possible that, some time in the eighteenth century, the threefold requirements of synchronous flowering of the two species, a south-west wind, and a mild spring permitting the ripening of the samaras were met. In

general, *U. glabra* flowers 4–6 weeks later than *U. carpinifolia*, but seasons, as in 1917, when flowering has been synchronous, are known (Christy, 1922).

NOMENCLATURE OF THE HUNTINGDON ELM

This elm has been variously described as a botanical variety, *vegeta*, of *U. glabra* Mill. (= *U. carpinifolia* Gled. sensu Rehder), by Loudon (1838); as a botanical variety, *vegeta*, of *U. dippeliana* Schneid. (= *U. hollandica* Mill. em. Rehder, = *U. carpinifolia* Gled. × *U. glabra* Huds.), by Schneider (1906); and as a species, *U. vegeta*, by Ley (1910). None of these epithets is satisfactory since the Huntingdon Elm is not a naturally occurring population but a horticultural clone. It should therefore be named in accordance with the International Code of Nomenclature for Cultivated Plants. Two epithets are provided in Loudon's description, the vernacular epithet Huntingdon Elm and the Latin epithet *vegeta*. Both these terms have remained in current use since then, and it seems most in accordance with the principles of the Code to adopt the vernacular term and designate this elm as *U. carpinifolia* Gled. × *U. glabra* Huds. 'Huntingdon Elm'.

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APPENDIX

Appendix on Definition of TG-continuity

Let D and I denote the relations of direct and indirect continuity, and superscript T, G, and TG, taxonomic, geographical, and taxonomic-geographical continuity, respectively. Then, if two plant samples p_1 and p_2 are biometrically defined by n characters

$$p_1 : x_{11}, x_{12}, x_{13}, \ldots, x_{1n},$$

$$p_2 : x_{21}, x_{22}, x_{23}, \ldots, x_{2n},$$

and all $$|x_{1v} - x_{2v}| \leqslant c,$$

c being the interval of comparison,

we have $$p_1 D_c^T p_2.$$

If $$p_1 D_c^T p_2, p_2 D_c^T p_3, \ldots, p_{n-1} D_c^T p_n,$$

then $$p_1 I_c^T p_n.$$

Describe lines running N.–S., E.–W., NE.–SW., and NW.–SE. through each p, and rotate all eight sectors any very small angle from the initial position. Let $p_1 N p_2$ denote that p_2 is the nearest sample to p_1 in any sector. Then, if $p_1 N p_2$ or $p_2 N p_1$, we have $p_1 D^G p_2$.

If $$p_1 D_c^T p_2 \quad \text{and} \quad p_1 D^G p_2,$$

then $$p_1 D_c^{TG} p_2,$$

and as before, if $$p_1 D_c^{TG} p_2, p_2 D_c^{TG} p_3, \ldots, p_{n-1} D_c^{TG} p_n,$$

then $$p_1 I_c^{TG} p_n.$$

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* Access to these records was given by kind permission of Major Sir Richard Proby.

† Access to this book was given by kind permission of Messrs. Laxton Bros.

THINNING CONTROL

D. R. JOHNSTON AND W. T. WATERS

SUMMARY

The authors examine briefly the relationship between growing stock and thinning production under various thinning intensities and suggest ways of forecasting and controlling thinning yields. There are five graphs.

INTRODUCTION

IN a number of Forestry Commission forests thinning production for the past few years has been considerably less than was forecast several years ago; in some cases as little as one-third of earlier forecasts. This is probably due to the fact that when the forecasts were made the crops were being thinned more heavily than was realized at the time and it was assumed that a similar intensity could be applied indefinitely. The object of this paper is to consider the relationship between growing stock and thinning production under various thinning intensities, to point out a common misconception in connexion with heavy thinnings, and to suggest ways of forecasting and controlling thinning yields.

For the sake of simplicity the discussion will refer primarily to basal areas rather than volumes. Basal area is far easier to measure than volume, but is a perfectly adequate expression of stocking or increment. It is therefore a more suitable measure than volume for all management purposes except for the sale of timber or the setting of piece-work rates.

THE DEFINITION OF THINNING GRADES

The thinning grades with which we are familiar in Britain, e.g. B, C, C/D, D,[1] were originally defined in qualitative terms, but since the publication of the Forestry Commission yield tables (Hummel and Christie, 1953) they have acquired a quantitative connotation. In reality, however, it is impossible to define a thinning grade which can be widely applied both qualitatively and quantitatively. For example, there is a great difference between two stands of the same top height, the one having fifty trees per acre with a mean basal area of 2 sq. ft. q.g. per tree and the other having one hundred trees per acre with a mean basal area of 1 sq. ft. q.g. per tree. In both cases the basal area per acre is 100 sq. ft. q.g., but there is a far greater cambial area (1:0·7) and therefore far more competition in the stand with one hundred trees than in the stand with fifty trees per acre. If each stand were thinned to a qualitative C/D grade, the one with the greater number of stems per acre would have to be thinned to a lower basal area than the one with fewer stems per acre. But it is possible to use one expression, for example, 'C/D grade', to indicate in a somewhat inexact sense both the type of thinning and also the basal area to be left after thinning, provided it is restricted to stands which were planted at about the same planting distances and which have received

[1] 'B' denotes a very light low thinning, while 'D' denotes a heavy low thinning.

similar thinning treatments throughout their lives. For the sake of brevity in this paper, the terms C/D and D grade are used in a purely quantitative sense. A 'C/D grade' is assumed to leave the same basal area after thinning as that given in the yield table while a 'D grade' is assumed to reduce the standing basal area to that of the yield table less 20 per cent.

YIELD TABLES AS STANDARDS OF GROWTH

By convention we refer to the Forestry Commission yield tables as a standard and we call the thinning they represent (for conifers) a C/D grade (except in the case of larches which are D grades). For each quality class yield tables give values for standing volume, standing basal area, increment, number of stems per acre, thinning production, &c., against age. But yield tables are so constructed that the various characters of the standing crop and total production are similar at a given top height, irrespective of age or quality class. They were compiled from data obtained from sample plots all over the country and one cannot assume that any particular crop will correspond with the yield table data appropriate to its age and quality class.

A crop may be potentially capable of growing exactly according to the yield table, but unless it was planted at the spacings assumed in the yield table and thinned in the same way, it will, at any given age, differ from the yield table pattern in one or more ways; for instance, in the standing basal area or the number of stems per acre. If there are more stems per acre, each tree will grow more slowly, even if the basal area per acre and the current annual increment agree with the yield table. In such a case, if the final crop trees are to reach the yield table dimensions at any given age, the basal area will have to be reduced so that, according to our quantitative definition, the thinning grade will become heavier, say a 'D' instead of a 'C/D' grade.

It is far more likely, however, that a particular crop will be incapable of growing exactly according to the yield table, no matter how it is treated. For a given top height, the current annual increment may be less. If such a crop is thinned to the yield table basal area, the girth increment of each tree and the thinning production will be less than the yield table. Conversely, if the thinning basal area implied by the yield table is removed, the growing stock will depart more and more at each thinning from that of the yield table.

It is apparent, therefore, that yield tables may be very misleading if they are used to forecast the future performance of a crop.

THE AIMS OF MANAGEMENT

The objects of management for a particular crop must imply a particular grade of thinning; perhaps a B grade to obtain pulpwood at 50 years of age, a D grade to produce sawlogs at the same age, or a grade which cannot easily be compared with the yield table. Whatever course of action is decided upon there will be an ideal allocation of total production between thinnings and final fellings, and what may be even more important, an ideal number of trees per acre at any one time

on which to grow the increment. For convenience, a proposed thinning régime may be described in yield table terms, i.e. it may be referred to as a C/D grade but as discussed above this does not imply that yield table basal areas or volumes will be obtained from thinnings or that the final crop trees will attain the same girths as those of the yield table. Since the basal areas, or volumes, which should be removed as thinnings or left as growing stock depend upon the total production, which can never be known precisely in advance, any forecast of future thinning yield must always contain an element of uncertainty. An important function of management is to reduce the uncertainty as far as possible and, even more important, to recognize a tendency to overcut or undercut in good time and to take steps to correct the tendency.

THE EFFECTS OF OVERCUTTING

Fig. 1 illustrates the effects of overcutting the increment. In this example we assume that the crop of Scots pine grows, in all respects, according to the yield table pattern for Scots pine quality class II and that it is the intention to thin to a C/D grade (i.e. exactly the same as the yield table).

The solid line represents the basal area growth with a C/D thinning grade while the dotted line represents the growth if, at each thinning, the basal area removed is 25 per cent. too much. The vertical lines represent the basal areas removed at each thinning—thus P represents the basal area before thinning and Q the basal area after thinning at age 45. Points R and S represent the corresponding basal areas if the thinnings have been consistently 25 per cent. too heavy. By age 40 the heavier thinnings will reduce the basal area before thinning from 129·5 sq. ft. q.g. to 114 sq. ft. q.g. This means that after three thinnings the thinning cycle has to be increased from five to eight years or thinning production reduced by over 50 per cent. if the basal area of the crop is to recover to that of a C/D grade.

Provided the stand structure is not destroyed, the overthinned stand can always recover if the thinning cycle is lengthened sufficiently, but by age 50 in the above example the cycle would have to be increased from five to twelve years during which time there would be no thinning production at all.

By age 60 the basal area would be reduced well below that of a D grade thinning and there might well be a permanent loss of increment as a result of the light stocking.

The extent to which the basal area can be safely reduced by heavy thinning depends to a large extent upon the intended rotation. If it were the intention to clearfell the Scots pine mentioned above at the age of 60 it would not matter if it has lost the ability to maintain its maximum current annual increment at that age and a deliberate and progressive reduction of basal area could be a perfectly reasonable treatment. If, however, at the age of, say, 35 a thinning forecast were made on the assumption that the thinnings up to that age had been a C/D grade when in reality they had been progressively heavier than a C/D it would not be long before the forest would be unable to supply its expected production. Management difficulties arise not from heavy thinnings but from heavier thinnings

than were intended. These can lead to a serious, albeit temporary, drop in thinning yield.

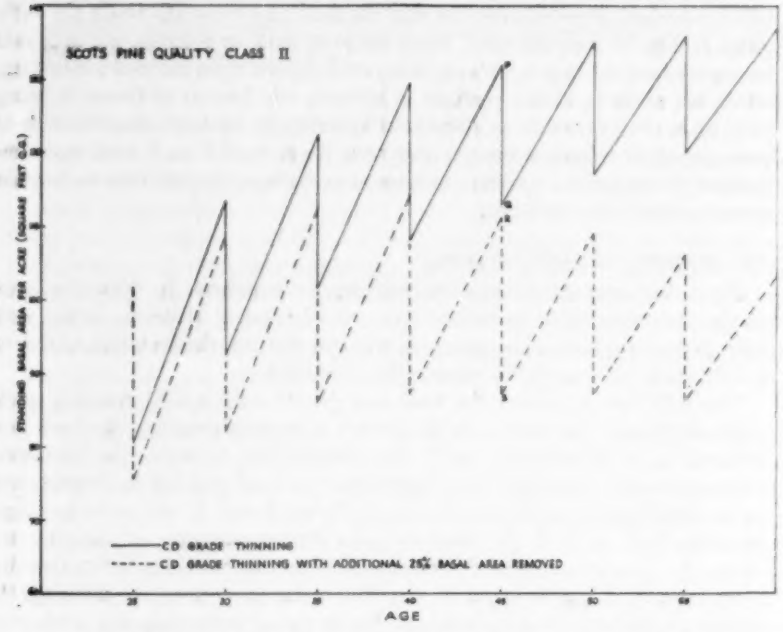
SCOTS PINE QUALITY CLASS II
STANDING BASAL AREA PER ACRE (SQUARE FEET Q.G.)
C/D GRADE THINNING
C/D GRADE THINNING WITH ADDITIONAL 25% BASAL AREA REMOVED
AGE

Fig. 1. Effect on basal area development of overcutting the increment by 25 per cent.

THE RELATIONSHIP BETWEEN THINNING GRADE AND THINNING PRODUCTION

There is a tendency to believe that the volume removed at each thinning is appreciably more under a D grade than under a C/D grade thinning régime, but this belief is to some extent fallacious. Fig. 2 illustrates the relationship between standing basal area and thinning production with Scots pine quality class II under the two thinning régimes. As before, the basal area development is represented by a solid line under a C/D grade, and by a dotted line under a D grade of thinning. By definition, a D grade reduces the basal area after each thinning to that of a C/D grade less 20 per cent. The points R, R_1, R_2, &c., represent the basal area of the crop after thinning to a C/D grade, while the points S, S_1, S_2, &c., are each 20 per cent. below the corresponding 'R' points and represent the standing basal area after a D grade thinning. The first D grade thinning in year 25 removes about 80 per cent. or 16 sq. ft. q.g. more than a C/D grade thinning.

Thereafter the reduced growing stock produces the same increment but concentrates it on fewer but larger trees. In years 35 and 40 a C/D grade thinning removes 21 sq. ft. q.g. and a D grade 23 sq. ft. q.g., but by year 45 they each remove about the same quantity.

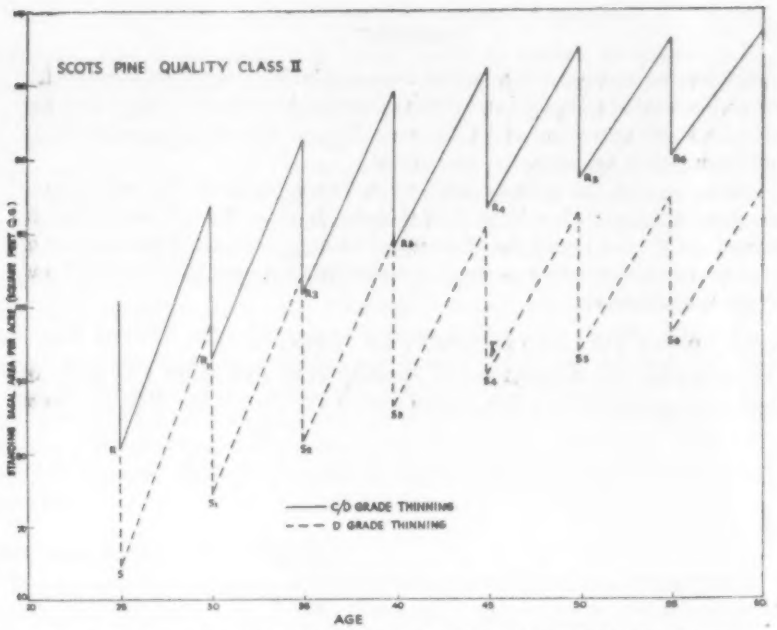

FIG. 2. Development of standing basal areas under C/D and D grade thinning régimes.

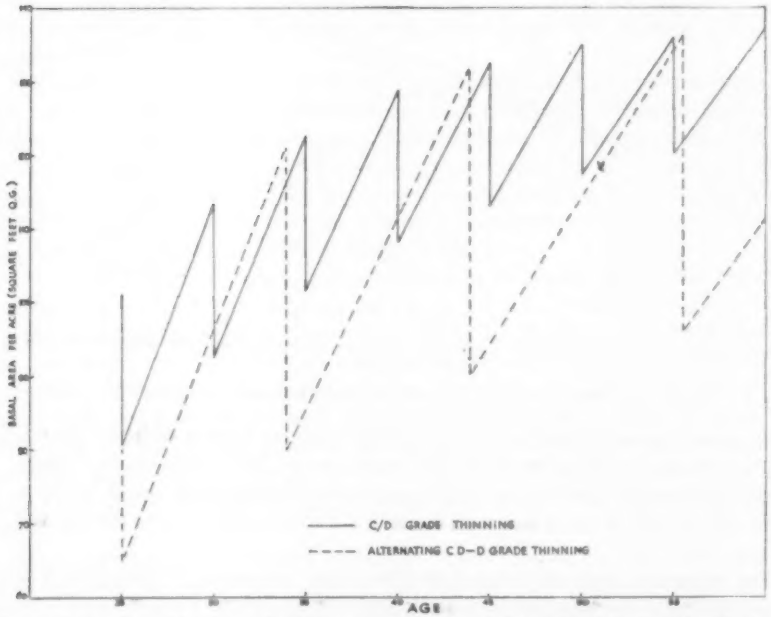

FIG. 3. Comparison of basal area development under C/D and alternating C/D–D grade thinning régimes.

An alternative method of conducting a heavy thinning is to reduce the standing basal area to that of a D grade and then to increase the thinning cycle so that the basal area builds up to that of a C/D grade (Fig. 3). Up to the age of about 35 the thinning cycle has almost to be doubled.

From 35 to 45 it has to be doubled, while from 45 onwards the cycle is more than twice as long. Such a method of thinning is not a D grade but rather an alternating C/D and D and the effect upon the crop, both as regards number of stems, mean girth and ring pattern, is somewhere between that of a C/D and a D grade of thinning.

DEFINITION OF TYPE AND INTENSITY OF THINNING

By definition, the development of standing basal area under a D grade of thinning is represented by a line parallel with the yield table line (Fig. 2). There

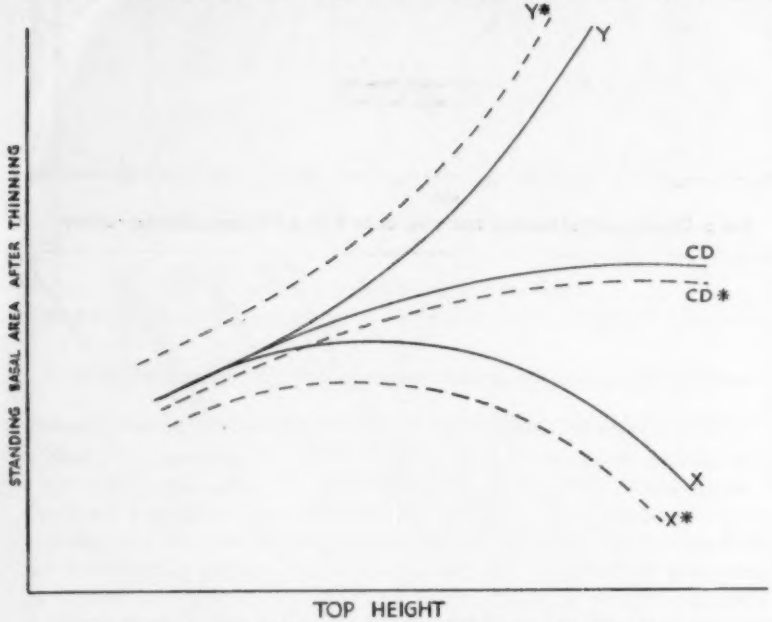

FIG. 4. Development of standing basal area under various thinning régimes.

is no reason, however, why a thinning grade, involving a quite different growth pattern should not be adopted. For instance, it would be possible to thin lightly at first and then to thin with increasing severity as represented by line X in Fig. 4 or to thin heavily in youth and then to leave the stand unthinned, as represented by line Y.

But whatever course of action is decided upon, a thinning régime, if it is to have a quantitative definition, can only effectively be prescribed in terms of basal area to be left after each thinning, not by the amount to be removed. If future

increment were known precisely it would indeed be possible to allocate it in advance between thinnings and standing volume for each stage of the rotation. In practice, however, future increment is not known precisely. Therefore, although the shape of a growth pattern can be decided, e.g. line C/D, Y, or X in Fig. 4 one cannot say in advance whether the line for a particular crop should follow C/D or C/D*, Y or Y*, X or X*. If the estimate of future increment is 25 per cent. too high and thinning is prescribed in terms of the basal area or volume to be removed one might cut 500 h. ft. instead of 400 h. ft. in each thinning. Since the growing stock will be in the region of 3,000 h. ft. the 100 h. ft. would pass unnoticed. After three thinnings, however, 300 h. ft. too much will have been removed and at the fourth thinning there will be only 100 h. ft. instead of 400 h. ft. to be cut unless one further reduces the growing stock to obtain the required yield. If, however, the thinning is prescribed in terms of basal area to be left after thinning, it will be apparent after one thinning that the thinning yield has dropped from 400 to 300 h. ft. Such a substantial short fall from the expected yield will immediately suggest that the original forecast was optimistic.

THINNING POLICY AND CONTROL

The first step in formulating a thinning policy is to decide what is required of the crop; that is to say, what size of tree at various ages, what ring width pattern, what rotation length, &c. These considerations decide the type of thinning to be adopted or, to express it by reference to Fig. 4, they decide the slope of the basal area/top ht. curve. The second step is to express the thinning policy quantitatively.

Although the future growth of the crop is not known, it is necessary to make the best possible estimate of future increment and to allocate, provisionally, this increment between thinning production and growing stock. Having decided the type of thinning and made an estimate of the absolute level of production, it becomes possible to prescribe the basal area to be left standing at various ages in the life of the crop. This prescription may conveniently be expressed in the form of a local basal area/top ht. curve as shown in Fig. 4.

The actual crop basal areas at any one time may be greater or less than those indicated by the local basal area/top ht. curve. A forest enumeration will show just how much each crop type departs from this curve. In Fig. 5 mean basal areas per acre at different ages, obtained from a forest enumeration, are represented by the points A, B, and C. These indicate that the older crops are being thinned less heavily than is compatible with the objects of management. There is, therefore, some surplus growing stock as well as a proportion of the increment to be harvested as thinnings during the following one or two thinning cycles; this will have to be taken into account in preparing short- and medium-term thinning forecasts.

Thus, having adjusted the crop basal areas to accord with the prescribed local basal area/top ht. curve, that part of the estimated increment which is not required to maintain the growing stock at the prescribed level will represent future

thinning production. If the actual thinning production in the future is greater or less than forecast, either the increment has been wrongly estimated, in which case it may be desirable to adjust the basal area/top ht. curve, or the prescribed standing basal area has in fact not been obtained because of under or overcutting. Periodic forest enumerations giving details of basal area by crop types will enable the forest manager to adjust his basal area/top ht. curve or his thinning intensity

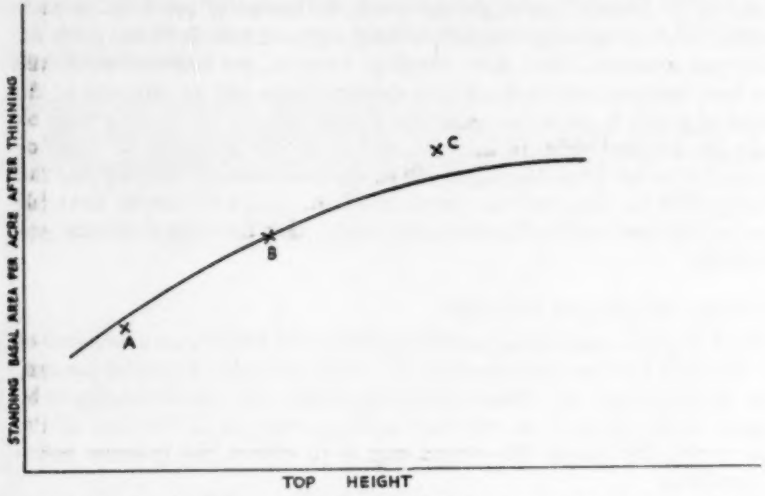

FIG. 5. Local basal area/top ht. curve compared with the results of a forest enumeration.

as the case may be. An additional complication occurs when basal area control is applied to mixtures. Because there are no yield tables for mixtures there are no standards of basal area for comparison, and even if there were yield tables they could only be applied to mixtures containing the particular proportion of each species assumed in the yield tables. Although the behaviour of mixtures, from the increment point of view, is not entirely understood, it is possible to suggest a technique of basal area control which will give reasonably reliable results. Let us consider a mixture of Corsican pine and Scots pine (*Pinus nigra* var. *calabrica* and *P. sylvestris*) having top heights of 59 ft. and 50 ft. respectively. According to the yield tables the Corsican pine, if pure, should have a basal area of 133 sq. ft. q.g. and the Scots pine a basal area of 108 sq. ft. q.g. At the forest in question the corresponding basal areas appropriate to the local thinning policy might be estimated as approximately 7 per cent. less, say 125 sq. ft. q.g. and 100 sq. ft. q.g. respectively. Therefore 1 sq. ft. q.g. of Corsican pine may be regarded as equivalent to 1·25 sq. ft. q.g. of Scots pine. In this example the stand would be correctly stocked (assuming it was the intention to thin to a C/D grade) if the total basal areas of the Corsican pine and the adjusted basal areas of the Scots pine amounted to the equivalent of 125 sq. ft. q.g. of Corsican pine, i.e. basal area of Corsican

pine + 1·25 × basal area of Scots pine = 125 sq. ft. q.g. Thus the stand might consist of the following proportions of Corsican pine and Scots pine.

Square feet q.g. of Corsican pine	*Square feet q.g. of Scots pine*		*Total square feet q.g. Corsican pine equivalent*
	Actual	*Corsican pine equivalent i.e. S.P. × 1·25*	
100	20	25	125
50	60	75	125
25	80	100	125

In each case the stand will be fully stocked.

Normally a basal area/top ht. curve will be prepared for each species, or each of the more important species in a forest. Although this curve may be used as a guide in the marking of all thinnings it will not be practicable to apply the thinning prescriptions exactly throughout every subcompartment or compartment; local variations either side of the prescribed basal area will be inevitable.

A periodic check on the results of the prescribed treatment will be made, not by individual subcompartments but by larger management units such as working (thinning) blocks, or even for the forest as a whole.

The principal check will be made after each forest enumeration which usually takes place every ten years. This enumeration will give the total standing basal area of each species in the forest, or in whatever management unit is being used for thinning control. This standing basal area will be compared with that prescribed in the basal area/top ht. curve, while the total quantity of thinnings removed since the last enumeration will be compared with that which was forecast. It must be remembered that a forest enumeration does not measure the standing basal area after thinning. At the time of an enumeration some stands will have just been thinned while others will not have been thinned for several years. Therefore, before comparing the measured basal area with the basal area/top ht. curve, one would normally have to deduct the basal area increment for half of the thinning cycle, since the basal area/top ht. curve refers to the standing basal area after thinning.

If the standing basal area does not agree with the basal area/top ht. curve the reason can only be that the thinning prescriptions have not been followed correctly. But the thinning production since the last enumeration may differ from the forecasts for one or both of two reasons; either the stands have not been thinned according to the basal area/top ht. curve or the estimate of increment was wrong. If the increment was estimated correctly and the stands have been thinned too heavily the thinning production will be greater than was forecast. If, on the other hand, the stands have been thinned according to the prescriptions but the estimate of increment was over-optimistic, then the thinning production will be less than expected. In the former case there will be no need to alter the

prescription but merely to thin less heavily. In the latter case the local basal area/top ht. curve may have to be adjusted.

A less precise control may be exercised during each ten-year period, annually if the control is by working blocks or at the end of each thinning cycle if the thinning is controlled for the forest as a whole. If there is a discrepancy between the forecast and the actual thinning production a series of small, temporary sample plots or relascope sweeps will give some indication of whether the thinning prescriptions are being correctly applied. If the standing basal area is found to agree with the basal area/top ht. curve the increment must have been wrongly estimated. A check of this nature cannot be very precise, but if there is found to be a substantial discrepancy between forecast and achievement it may be desirable to make a tentative adjustment either to the basal area/top ht. curve, to the thinning forecast, or to both.

It would be unrealistic to imagine that this procedure will automatically result in perfect control of growing stock or thinning production. It will, however, provide a standard and a means of adjusting that standard as more and more data become available.

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CLIMATIC SUB-REGIONS OF WALES

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SUMMARY

A short paper with three maps extending to Wales the system of regionalization suggested for Scotland by Anderson and Fairbairn in their *Division of Scotland into Climatic Sub-Regions as an Aid to Silviculture* published as Bulletin No. 1 of the Forestry Department, University of Edinburgh, 1955.

INTRODUCTION

HAGEM (1931) made the first serious attempt to use the behaviour of the vegetation as an aid in defining climatic sub-regions for forestry purposes by determining and differentiating those areas in Norway which are climatically analogous to particular areas in North America. In this way he facilitated the introduction of trees for use in Norwegian silviculture. The same approach has been used by Anderson and Fairbairn (1955) for Scotland to 'aid in correlating the sub-regions in Scotland with regions of a similar nature in other countries from which it may seem desirable to introduce particular tree-species or strains of tree-species, or methods of silviculture which have been more fully tested there'. These authors concluded that, despite the wide and often complicated variation in the geological strata and its influence on the physiography of Scotland, the primary basis of regionalization must be climate. They combined zonation into growing-season temperature zones with a zonation into growing-season rainfall zones to give fourteen sub-regions differing in respect of these two major factors.

The present paper is an attempt to extend the Anderson–Fairbairn technique to Wales. The same parameters of growing-season temperature and growing-season rainfall have been used since their separate and combined effects are generally considered to be the truly active climatic factors in silviculture especially in respect to tree growth.

LENGTH OF THE GROWING SEASON

It is generally accepted by agriculturalists that the growing season for crop plants begins when the mean daily temperature reaches a threshold temperature of 42° F. This is the temperature[1] at which the first shoots of young grass are said to appear. Anderson and Fairbairn, on the other hand, follow Hagem and fix the commencement of the silvicultural growing season in Scotland as the day in spring when the mean daily temperature has risen to 7·5° C. (equated to

[1] Presumably the temperature recorded by a thermometer placed in a louvred box ('screen') some 4 feet above the ground. This is hardly an index of conditions within the plant environment.

45° F.) and the end of the growing season on that day in the autumn when the mean daily temperature falls back again to 45° F. The silvicultural growing season is thus defined as 'that period of time—in number of days—which lies between the first day in spring whose mean temperature rises to 45° F. and the first day in autumn whose mean temperature fails to reach 45° F.'[1]

Since altitude is obviously not the only factor affecting the temperature and hence the length of the growing season, the effect of altitude is eliminated before the length of the growing season is calculated. A decrease of temperature with increased height at the rate of 1° F. for every 300 feet of ascent is assumed. Values of the unadjusted and adjusted mean monthly temperature for Rhayader (Radnorshire) and Welshpool (Montgomeryshire) are given in Table I, and the method of calculating length of growing season from temperatures reduced to sea-level is illustrated for Welshpool in Fig. 1.

TABLE I. *Mean monthly temperatures—actual and adjusted to sea-level—for two Welsh stations*

	Rhayader (757 ft.)		*Welshpool (254 ft.)*	
Month	*Actual*	*Reduced* (+2·5° F.)	*Actual*	*Reduced* (+0·8° F.)
Jan.	38·2	40·7	39·0	39·8
Feb.	38·0	40·5	39·5	40·3
Mar.	40·8	43·3	42·4	43·2
Apr.	44·6	47·1	46·6	47·4
May	49·7	52·2	51·9	52·7
June	54·9	57·4	57·1	57·9
July	58·2	60·7	60·4	61·2
Aug.	57·6	60·1	59·7	60·5
Sept.	54·1	56·6	55·7	56·5
Oct.	48·0	50·5	49·3	50·1
Nov.	42·1	44·6	43·1	43·9
Dec.	39·2	41·7	40·3	41·1
Year	47·1	49·6	48·8	49·6

Fig. 2 shows the length of the growing season of the various parts of Wales adjusted to sea-level. Four sea-level growing season zones can be recognized: zone W[2] with less than 220 days; zone X from 220 to 240 days long; zone Y from 240 to 260 days long, and zone Z over 260 days long. Maritime influences are clearly demonstrated in the coastal areas of Anglesey, Lleyn, Pembrokeshire, Carmarthenshire, and Glamorgan.

[1] Such a parameter does not provide any indication of intensity of growth. For this purpose 'accumulated temperature', i.e. the number of 'day-degrees' above an accepted threshold value (e.g. 45° F.), may prove a better heat index.

[2] Since sea-level growing seasons in Wales are everywhere greater than in Scotland, suffixes W, X, Y, and Z have been selected to avoid confusion with suffixes A, B, C, and D adopted for Scotland by Anderson and Fairbairn.

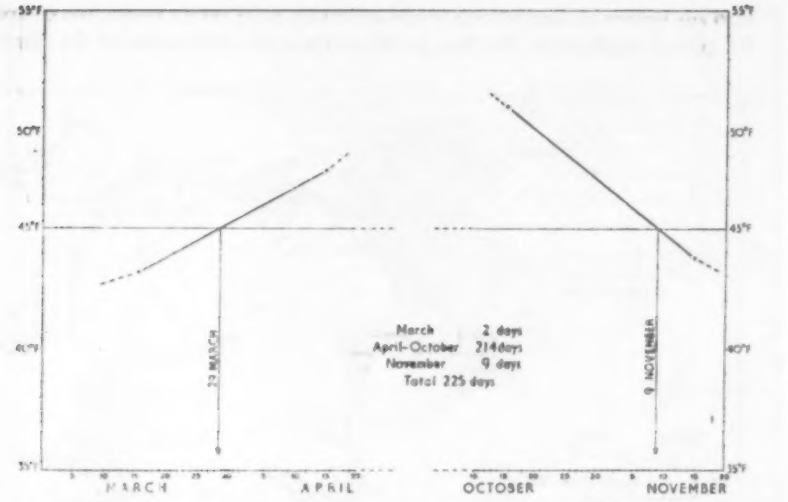

FIG. 1. Welshpool, Montgomeryshire (254 feet above sea-level). Length of growing season adjusted for altitude.

GROWING SEASON RAINFALL

From the silvicultural viewpoint the amount of rainfall received during the growing season is obviously of primary concern in any climatic classification. This is the second or moisture parameter for regionalization. Rainfall aggregates for the months of May to September inclusive for 105 stations were used as the basis for drawing the isohyets shown in Fig. 3. The pattern of rainfall distribution for the growing season displayed is similar to that for the year, but with aggregates for the former generally amounting to about 42 per cent. of the annual total. The relatively wet heathland of Wales and the drier coastlands and eastern borderland are well illustrated.

CLIMATIC SUB-REGIONS

Superimposition of the four sea-level-growing-season zones (Fig. 2) and the four growing-season-rainfall zones (Fig. 3) provides climatic sub-regions in terms of these two parameters. Limited adjustments of boundaries were necessary to make them coincide with features on the map and on the ground but the result is a broad climatic regionalization of Wales. The position of forty detached sub-regions, in which the climate may be defined in precise statistical terms, is shown in Fig. 4.

It should be recognized that the lines of demarcation in Fig. 4 of necessity are based on the average values or intensities of the parameters considered. This should not lead to the conclusion that variability of the climatic features is not considered important. Variability both within and between seasons is of the greatest significance to foresters. But the inclusion of a measure of variability

into any system of classification would inevitably make such a system too complex for general application. Further, in the cartographic delineation of the climatic

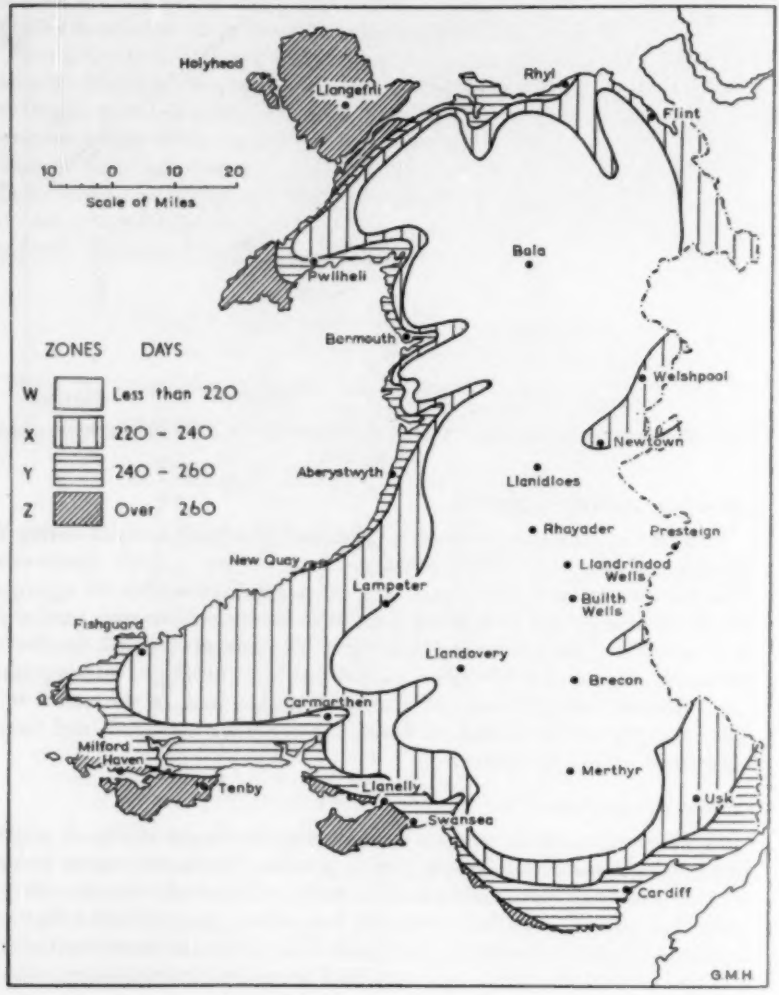

FIG. 2. Lengths of growing season in days adjusted to sea-level.

regions, it should be understood that the boundary lines between the type regions are not sharp but rather that they represent transition zones and appear in their true role as indicators of direction of change.

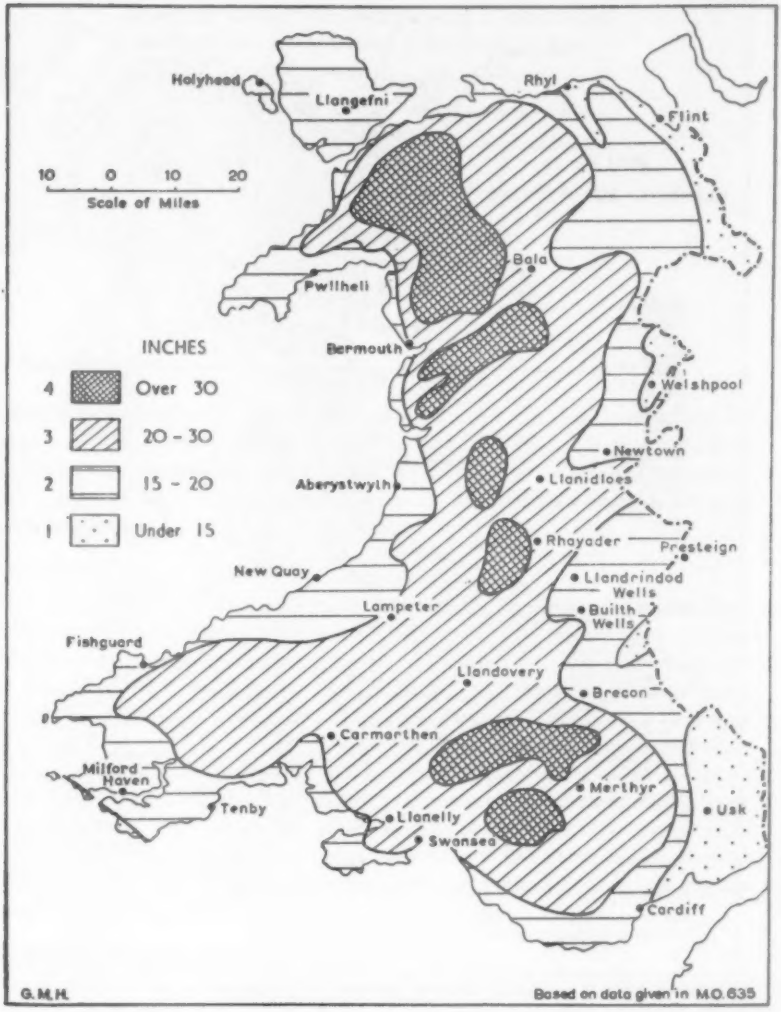

FIG. 3. Average Rainfall, April to September, 1916 to 1950.

ALTITUDINAL CORRECTION WITHIN SUB-PROVINCES

The altitudinal effect was deliberately eliminated from the figures of growing season length used in the construction of Fig. 2, since it was felt that some factor, e.g. maritime influence or illumination, or some combination of factors, was exerting an important influence on the length of the growing season. Regionalization having thus been established it now becomes necessary to make allowance

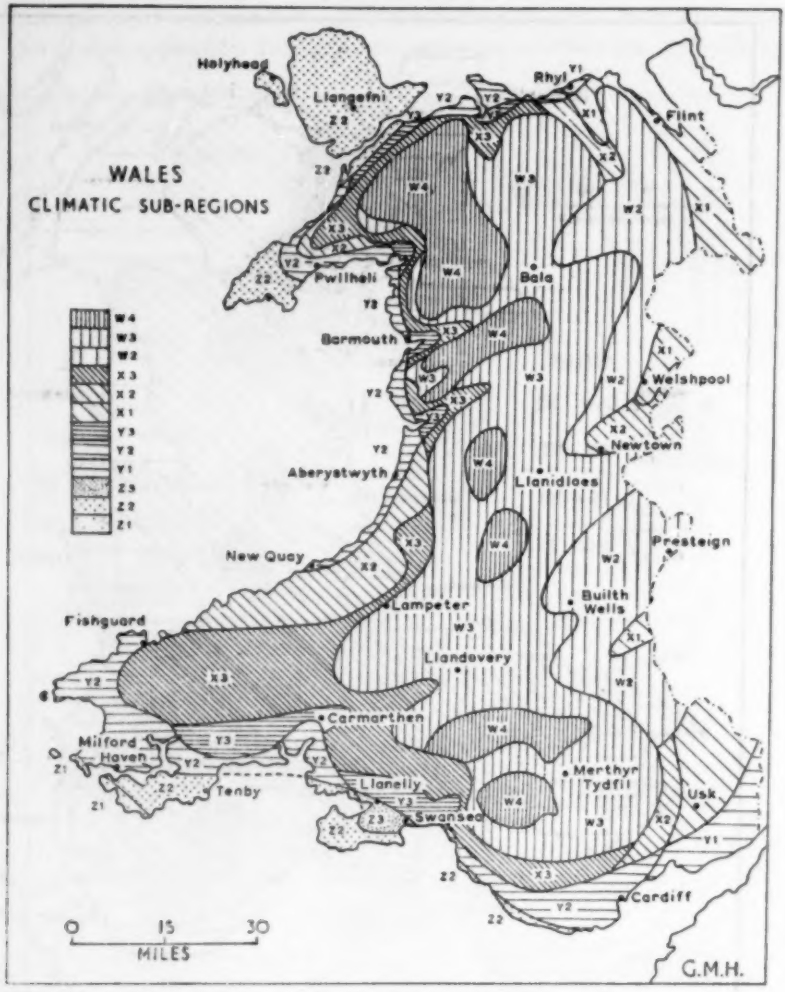

Fig. 4. Climatic sub-regions of Wales.

for the height of any particular site above sea-level in respect of each climatic sub-province.

To achieve this purpose length of growing season for all stations within each zone W, X, Y, and Z respectively was plotted against altitude. From the smooth graphs drawn between the points so obtained it is possible to read off for each of the zones W to Z the figures given in Table II.

TABLE II. *Changes in growing season length in days with altitude in the various growing-season zones*

Altitude in feet	*Zone*			
	W	*X*	*Y*	*Z*
Sea-level	220	233	260	270
100	214	229	242	255
200	209	224	237	248
300	206	221	236	
400	203	219	235	
500	200	218	234	
600	198	216		
700	196			
800	194			

Once a sub-province within which any given site lies has been found by reference to Fig. 4 it is necessary to refer to Table II. Knowing the altitude of the site in question the approximate length of its growing season can l e estimated. In this way the site can be related to sites in climatically analogous areas in Wales or elsewhere.

CONCLUSION

The present paper is an attempt to extend to Wales the system of regionalization adopted by Anderson and Fairbairn for Scotland. It is to be hoped that the result, expressed cartographically in Fig. 4, will provide a sounder, quantitative basis than the present procedure for comparing and relating areas in Wales which resemble one another in respect of the main factors of climate as they influence silviculture. The present procedure is largely the outcome of trial-and-error. Even so the use of simple temperature and precipitation values to define boundaries of sub-regions is far from satisfactory. Some measure of thermal efficiency and precipitation effectiveness (i.e. allowing from evaporation and transpiration losses) is essential in any scheme of regionalization if the direct environmental influence of climate on silvicultural techniques and methods is to be adequately assessed and fully appreciated.

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THE BRITISH ASSOCIATION AT CARDIFF, 1960

WE give below, at a member's suggestion, a summary and some extracts from three papers read to the Forestry section at the meeting of the British Association for the Advancement of Science at Cardiff from 31st August to 7th September 1960.

We appreciate that there are defects in this method of presentation. The experiment is made because we have space only for a very small proportion of the papers read at any meeting. Some of the papers are to be published in full elsewhere and information about this can probably be had from the authors. The papers selected are those by T. R. Peace, Chief Research Officer, Forestry Commission; G. B. Ryle, Director of Forestry for England and until recently Director for Wales; and A. W. Camburn, Wood Buyer, Mersey Division, Bowaters United Kingdom Pulp and Paper Mills Ltd., Ellesmere Port, Cheshire.

In addition to the above, papers were read by B. T. Wood on the *Contribution of State Forests to the Economy of Rural Wales*; by John Q. Williamson, John Casson and L. A. King, and by J. W. Houldsworth on the *Afforestation of Derelict Land*; and, at a joint session with the Botany section, by P. F. Wareing, J. Moorby, K. A. Longman, and M. Black on the *Physiology of Forest Trees*.

T. R. Peace. *The Dangerous Concept of the Natural forest.* Discussion section.

Discussion

It is clear that the natural forest is worthy of considerable study, since it provides an example of trees and their accompanying organisms established in a relatively stable and balanced environment. As such it may well give information of value for managed forestry. It becomes dangerous only when it is elevated to the level of a concept of desirability, as an example which foresters should endeavour to copy. Used in this way it can lead, and has led, to the adoption of practices, not because they will give enhanced and sustained production, but merely because they appear relevant to this unthinking ideal.

I have tended above to stress particularly those instances where silvicultural practice based on the attributes of the natural forest, such as mixed species, mixed ages or the use of native species, may lead to worse rather than better growth. In so doing I have certainly tended to give a biased picture of their general effect. This is perhaps inevitable, since the main purpose of this paper is to stress the danger of adopting the concept of the natural forest as a basis for silviculture, instead of founding it on a scientific consideration of each set of conditions without initial bias for or against any particular practices.

There has always been a tendency in a growing and imperfectly understood science, such as forestry, to enunciate at an early stage general principles, which it is hoped may serve as signposts through the fogs of ignorance. Biologically at any rate, such a procedure is almost invariably dangerous. The interactions of organisms

with one another and with their environment are so complex that what appear at an early stage to be rules, may merely be coincidences. At present we lack the necessary basis for any embracing simplifications. If we are to make progress in the acquisition of the knowledge that is so necessary for a proper understanding of forest processes, it is dangerous to limit ourselves at this stage by the enunciation of general principles, even if they appear to have a moderately sound foundation. To burden ourselves with a concept as vague and ill-founded as the inherent desirability of the natural forest is doubly dangerous.

G. B. Ryle. *Forestry in the Economic Development of Wales* (Summary only).

The geological chance which robbed Wales of the Scots pine robbed her also of any real forestry tradition. Up to the advent of the Forestry Commission in 1920, forestry in the economy of Wales was a wasting asset and even between 1920 and 1939, the area felled over probably exceeded the 58,000 acres planted. Unemployment in the 1930's in South Wales gave impetus to pioneer forestry work in the mining valleys, but the six years of war were six years of slaughter for the woodlands remaining.

The impact of the slowly growing Forestry Commission upon the rural economy of Wales prior to 1939 had gone largely unnoticed. It was, however, important and welcome in the sick-at-heart marginal hill farm districts and the start made enabled it to expand in the next 21 years by no less than 171,000 acres and at the same time there has been an encouraging surge of activity by private landowners.

Where is this leading to? What will be its effect on the economy of Wales?

In 1958 the Government recognized that the theory of a strategic timber reserve was no longer realistic but, with the Zuckerman Report, the Mid-Wales Investigation Report, and the report on crofting conditions in Scotland all in their hands, and no doubt too considering the world's increasing needs for timber, they did not hesitate to reiterate the need for a continued policy of forest expansion both for economic reasons but also for the social benefits which would accrue especially in the upland areas of Scotland and Wales.

The steady change from sheep to timber in the degenerating farms will continue irrespective of subsidies and it is right that it should do so because advances in our education, health, and other social services make it impossible to cater for these lonely and primitive places just as it makes these places unwanted by the rising generation. The economic integration between sheep and timber on the less remote hill farms is proving more difficult and it will take time to remove the mutual distrust which exists.

Good commercial forest management is practised now in Wales over 330,000 acres and 500,000 acres of state and private forest might well be considered as a realistic target for the present century. Most of this will have been extracted from rough grazings of marginal hill farms and, disregarding sawmill or wood factory jobs, will have increased employment from a sinking figure of 4,000 farm workers to 9,000 or more forest workers (one man for fifty acres on a perpetual yield basis against less than one man for a hundred acres).

Important as the increase in employment is, it seems better that any possible reduction in livestock should be weighed, not against increased employment, but against expanding timber production. On current techniques it would be reasonable to forecast the approximate acreages and annual yields of our ½ million acres of Welsh forest as below.

Species	*Thousand acres*	*Mean annual yield per acre (cu. ft.)*	*Total annual yield (million cu. ft.)*
Pines . .	70	100	7
Larches . .	30	100	3
Douglas . .	30	150	4
Spruces . .	320	150	48
Hardwoods, &c.	50	70	3
	500		65

Thus we might expect 65 million cubic feet per annum in the first half of the next century against 6 million cubic feet now.

It is known that nearly 150,000 acres of hill land have been withdrawn from grazing since the war but that sheep production has continued to increase and that there is still scope for better livestock production in a selectively diminishing acreage. It would be interesting therefore if the agriculturists could tell us whether they could still maintain today's level of livestock production with this further increase of 170,000 acres of forest. If not, what reduction of livestock would there have to be? If we can get an answer to that question, we shall have gone a long way to alleviate long felt anxiety in the hills.

There need be no anxiety about marketing this additional output. The production in planks and boards from 65 million cubic feet would be about 30 million cubic feet compared with Britain's annual consumption of 400 million. The demand for pitwood for South Wales though lessening might still absorb 7 million cubic feet leaving 28 million cubic feet of small dimensional material to supply fencing, telegraph poles, and a little of the 200 million cubic feet needed by expanding pulp and manufactured board industries.

Forests will also improve the economy of Wales by an increase in the number of tourists. The camping, caravanning, and touring facilities created in the Forest Parks have already been quoted as models by National Park authorities and there is no doubt that such facilities will be expanded and multiplied. A well-managed forest, even if primarily a commercial one, will always be aesthetically satisfying once it has passed the adolescent stage.

Lastly as regards water supplies, it is well to remind ourselves that it is the steady supply throughout the seasons and throughout periods of drought or storm that is of importance to water undertakings rather than the gross inflow into the reservoirs and that there is no doubt at all that a well-forested catchment area serves far the best to even out the flow from the hills into the streams and thence

into the reservoirs. In all some 25,000 acres of Welsh catchment areas are under systematic forest management.

A. W. Camburn. *Newsprint from Welsh Trees can help to improve the economy of rural Wales.*

We give below some extracts from Mr. Camburn's paper.

On the species tried

When the decision was taken to build a pulpmill alongside the paper mill at Ellesmere Port it was decided to experiment with the use of home-grown pulpwood, having in mind the very large quantities of wood that would be coming available from state and private forests during the next few decades. The Forestry Commission were approached and after negotiations had taken place they guaranteed a percentage of the requirements. Discussions also took place with the timber trade and I commenced visiting estates and potential suppliers to discuss the requirements of this new mill and arrange for future deliveries. It should be remembered that at that time the use of home-grown pulpwood was to be experimental. The total requirements of the mill were estimated to be about 2,000 tons per week and the aim was to use 50 per cent. home-grown and 50 per cent. imported pulpwood. Many months before the groundwood mill commenced production, home-grown pulpwood was purchased and a large stock created, in order to assist the timber trade and growers to develop a supply organization. At the same time a shipment of this material was sent to one of the Bowater Pulp Mills in Norway and extensive tests were carried out to establish the suitability of the home-produced raw material. After the results of these trials had been received it was decided to start up the mill experimentally using 100 per cent. home-grown pulpwood. Bearing in mind the various species of conifers available in this country, the early purchasing programme included a fairly high percentage of Scots and Corsican pine and Douglas fir. In Canada and Scandinavia these species are diverted to the chemical pulpmills and the groundwood mills use mainly Norway spruce and Sitka spruce. It was hoped that the new mill would be able to make use of these species, but very early in the trial runs it became obvious that these species were going to create many difficulties. Douglas fir tinted the pulp and made it difficult to control the colour of the newsprint. It also presented difficulties in the debarking process. The pine produced a much shorter length of fibre and this affected the strength of the paper, but the main difficulty with these species was the resin content which blocked the cutting surfaces of the grinder stones and thereby ruined the quality of the pulp. Particles of resin would reach the papermaking machines and leave black spots in the paper. The percentage of these species was gradually reduced but as the mill still experienced difficulties it was decided to eliminate them altogether and use only Norway and Sitka spruce. It should be noted that imported pulpwood for groundwood mills is almost 100 per cent. spruce. The requirements of spruce were therefore increased from approximately 600 tons per week to 2,000 tons per week and as you can imagine this was not easy to obtain.

On the high moisture content of home-grown logs

The high moisture content of home-grown wood results in a number of logs sinking in the water flume used to transport logs from the storage bunkers to the grinder feed system and this can cause considerable stoppages. This high moisture content also means that many more tons of home-grown wood have to be handled compared with the drier imported wood. Although at first we were concerned with the high moisture content, as this considerably increased the price we had to pay for the actual fibre, it has been found advantageous in the grinding process and I am pleased to be able to advise you that the special character of this rather fast-grown, high moisture content, home-grown wood has resulted in the new mill being able to produce mechanical pulp which compares favourably in quality with imported pulps.

On the cost per long ton

On the subject of cost, the very high moisture content, plus bark at 10/13 per cent. means that we are obtaining only approximately 34 per cent. bone dry fibre. This is equal to £22. 16*s*. per bone dry long ton compared with the price of £7. 12*s*. to £8. 10*s*. quoted in the Sandwell report on the 'Small Pulp Mill Survey'. Notwithstanding this I am hopeful that by increasing the efficiency of the mill, possibly by making the unit larger, but primarily by improving the cost of winning the raw material from the forest it will be possible to compete economically with imported pulp.

On the immediate future

Future supplies would seem to be assured, our concern is with the immediate future. As you know the forests of this country are very unbalanced as far as age groups are concerned and at the present time insufficient thinnings are available to support the present mill. Supplies are being drawn from as far afield as Fort William in Scotland and Dartmoor in the south, also shipments are being received from Northern Ireland and the Isle of Mull. Even so it has been necessary this year to import three shipments totalling over 10,000 tons of pulpwood from Canada and Finland.

If more spruce could be made available during the next few years, it would help develop this market for the time ahead when the market is likely to be overloaded with thinnings. This could be achieved by more selective felling of areas that may have difficulty in withstanding the wind in a few years time. I am not proposing wide scale clear felling or even total short rotation cropping, although this might be the most economical way of growing pulpwood, for the grower would receive payment for the crop before compound interest gathered too much momentum. But by carrying out some clear felling during the next few years it would remove the need to import this material and at the same time assist the grower to balance the age groups in individual forests. A certain amount of this is already being done and I would stress that if the practice could be extended a little more there would be no need to spend dollars on a commodity that is available in this country and which in the years ahead may be surplus to the requirements of the timber trade.

On stability of labour

The felling, extraction, and converting of the thinnings and mature timber from these forests is mainly carried out by contractors working for the timber merchants, and although these men do a hard task extremely well and as cheap as is possible at the present time, the very nature of their work and the present method of selling thinnings leads to a rather nomadic life.

As the volume of thinnings increases, it will become necessary to attract an ever increasing labour force to this industry and in order to do this merchants will be obliged to offer a more regular form of employment. At the present time the majority of thinnings are sold by tender or auction which possibly results in a different merchant purchasing each parcel as it becomes available in each forest. This often results in the labour transferring to the new parcel, which will offer a longer period of employment and leaves their previous employer to clear possibly the most difficult part of the parcel, with either a depleted labour force or newly engaged men who are difficult to obtain due to the short duration of the job. The merchant has then to tender for parcels in other forests in order to meet his commitments with his customers. If successful he has to move all his gear which can be somewhat expensive and then begin the recruitment of labour in a new area, most likely tempting labour to leave another merchant already working in that forest. Since commencing to purchase pulpwood for the new groundwood mill I have seen this happen on many occasions.

The grower and consumer both rely on the merchants to undertake this difficult work and if they are to cope with the additional volume of thinnings becoming available in the future they will require much more stability. I appreciate that there are a number of 5-year contracts in being, but few of these are large enough to permit a merchant to keep his labour force engaged throughout the year and he has to enter into competition for the balance of his requirements. Surely it is possible for the grower, converter, and consumer to get together and work out some scheme to eliminate this migration of labour, to which I have referred, at the same time giving the grower a fair price for the thinnings, the consumer a stable price for his raw material, and the merchant a satisfactory margin of profit which will permit him to expand as the thinning programme gains momentum. Timber merchants might be invited to tender for all thinnings from one forest, with prices to be re-negotiated each year, but on the understanding that if the successful tenderer was unable to manage the total quantities in the future, another merchant would be given the opportunity of working in the forest with him. The merchant would be able to build up a regular labour force, which would enable him to give a better service to the grower and also make it possible for the consumer to place orders covering a much longer period, thereby bringing stability to all three sections of the industry in which we are all concerned. This could quite easily lead to the establishment of other communities near the forests and similar to the Forestry Commission villages, in which the permanent timber contractors would reside eliminating much wasteful travelling time and bringing more prosperity to the rural communities.

REVIEWS

C. D. F. Reventlow. *A Treatise on Forestry*. Society of Forest History, Hørsholm, Denmark, 1960.

Review by H. M. Steven

COUNT REVENTLOW was a Danish nobleman who died in 1827. During his lifetime he served his country in the highest offices, including that of Lord Chancellor, as some of his ancestors had done before him, but today he is remembered as a forester and, above all, for initiating ideas about thinning which remain characteristic of Denmark today. It is of interest to note that he visited England, as part of his 'grand tour' of European countries, after completing his education at Søro Academy, whose beautiful woods were visited by some members of the Society of Foresters during their tour of Denmark in 1955, and he acknowledges his debt to John Evelyn, to Dr. A. Hunter who added notes to the 1776 edition of *Sylva*, and to T. Nichols, purveyor of the navy for Portsmouth dockyards. He also drew inspiration from such a giant in the German forestry world as G. L. Hartig, and also from German foresters who settled in Denmark, such as G. W. Brüel. Reventlow adopted the then German ideas of regular forests and the use of what is now called the Uniform or Shelterwood Compartment System for regeneration, but he disagreed with Hartig's ideas of late, light, and infrequent thinnings. This disagreement was based partly on what he had seen and learned in England and France, but principally on the pioneering stem analyses that he carried out in his own forests and had made in the royal forests in Zeeland. He recorded ring widths, hence increment, at various points in the stem and in trees of different ages and at different espacements from other trees. He then made what are called 'experience tables' which are very similar to the current Danish Yield Tables by Professor C. Mar: Møller. He was concerned principally with oak and beech because conifers which had been first used in Denmark in the eighteenth century by J. G. von Langen were not yet common in Reventlow's time. Count Reventlow's principal contribution to forestry knowledge was, therefore, his studies to show the advantages of early, frequent, and heavy thinning which made possible a drastic reduction in the rotation for a given size of tree—120 years for oak and 80 years for beech—and also greatly improved the financial returns.

Reventlow completed his 'Treatise' about 1816, but, owing to financial difficulties at that time, it was not published. He left two manuscripts, one in Danish and one in German; the 'Treatise' was published in Danish in 1879, and there was a German edition in 1934. The English-speaking forestry world is indebted to the Danes who have made this classic available in English and, in particular, to the Society of Forest History in Denmark and to Professor A. Howard Grøn, the well-known Danish forest economist, who edited this edition as he did the earlier German one.

Paul E. Vezina. 'Recherches sur les conditions de lumière et de précipitations dans les forêts traitées par la coupe progressive par groupes'. *Memoires de L'Institut Suisse de Recherches Forestières*. Vol. 36, fasc. 2, 1960. Pp. 137.

Review by W. A. Fairbairn

THIS publication will be of considerable value to those interested in light intensity and forest influences in silviculture and management, covering, as it does, careful research on solar radiation and precipitations in forests treated by progressive fellings by

groups. It is divided into four parts; the introduction and enumeration of the problems; the method of investigation and the research organization; the results of observations and measurements; finally a résumé and conclusions. These are followed by a summary given in German, Italian, and in English. The whole concludes with an extensive and useful bibliography in which 90 references are given from international sources.

In the foreword the author states that the invention of precision instruments for the measurement of light and the necessity of recording other scientific measurements in silvicultural techniques, have made photometric studies essential. The action of light intensity on regeneration by progressive fellings by groups is described and it is pointed out that light plays a preponderant rôle in silviculture. The author stresses that this rôle is shown in the regeneration of forests, in the development of the young growth as well as in the choice, orientation, and dimensions of the groups; he states, too, that the reactions to light of different species are decisive in ensuring the correct proportion of species in mixture, their growth and quality, and finally the prevention of disease in the young regeneration. It is also pointed out that light must not be considered solely, since a number of factors is involved, including temperature and the balance of available moisture, but that among all the meteorological factors, solar radiation and precipitations are of primary importance.

The basic requirements of the study included giving numerical values for light and precipitations on the chosen sites and determining their influence in the natural regeneration of one light-demanding and of one shade-bearing species; then finally, on a trial basis, showing the influence of light intensity and soil moisture on the development of a light demander.

It is worthy of note that the research was confined, wisely, to these two major influences, ignoring photosynthesis, photoperiodism, and phototrophism which are, however, defined; this is to be commended, for these phenomena, not yet completely investigated, are elsewhere subjects of separate research by specialist workers. The author restricted his investigations to one forest region and to the two main species, ash and beech; the work was carried out in the forest of the École Polytechnique Fédérale, Zurich, since the femelcoupe system has been meticulously applied there and since the two species are found there regenerating successfully.

The methods followed in the investigations are described in considerable detail. Careful consideration was given to light measuring instruments used by workers past and present; one luxmeter, several Bellani pyranometers, and a number of rain gauges were employed: the reviewer considers that two, duly calibrated, luxmeters should have been used as one instrument has obvious limitations when measuring first in a forest stand and then, no matter how soon afterwards, in full light in the open. The luxmeter was used in the forest in plots 5 metres square, the readings being taken along the sides of the square and on the diagonals, a method which has some disadvantages. The pyranometers, for which the factor of variation in each was determined, were used extensively in gaps and in areas of young regeneration, for varying periods and on various sites so that the equipment could be used to its best advantage.

The author also used photographic methods with a view to showing the relationship between light measurements in forest stands and the silviculture of these stands. Photographs of the canopies in seven recorded plots are shown, for four of which, the number of stems and volume per hectare, the relative light intensity, and the percentage of sky in the canopies are recorded, making a useful contribution in the use of the camera in canopy assessment.

The measurements of precipitations in the groups, the extraneous factors considered,

the equipment used, and the method of their employment are also described meticulously. The pluviometric observations were carried out during the vegetative period of 1957, in a gap measuring 78 metres from north to south, by 50 metres, in which cone-form regeneration occurred of ash, beech, and spruce; twelve rain gauges were used, with one as a control in the open, during 5 months in a summer of heavy rainfall; the interception percentage was determined for each gauge. It is unfortunate that precipitation records were not able to be kept for the whole period of the study, since precipitations in winter have a decisive effect on soil moisture availability during the growing season; evaporation figures would have been useful.

Next follows a description of the research plots, their siting and the instrument location, light intensity and precipitation measurements having been made with due regard to the occurrence of natural regeneration in mixed stands with gaps and clearings and in the open, for purposes of comparison. The natural regeneration of ash and beech occurring in gaps in the forest was closely studied; there are observations on the young growth of each species giving the age and number of ash and beech in the group, the silvicultural treatment, the length of the terminal shoots, the damage caused by frost and finally the mortality rate, a most valuable series of observations. Then the actual sites and plots are described in detail recording the altitude, geology, soil, topography, and the forest composition. There are also tables recording the dry weight of a season's growth of ash under different light intensities and the analysis of the dry weight of plants as a function of light and of soil humidity.

The author describes how in the femel-coupe system a variation in felling is used in getting natural regeneration, obtained for the greater part, from shelter-wood fellings over small areas; how, when the fellings are intensified, they result in gaps with regeneration, established partly under shade and partly in the open, and wherein the light intensities and precipitations vary. His results show that the silviculturist has control over important ecological factors, that he can vary the light intensity, the dimensions of the regeneration group, the direction of its enlargement, and that he is enabled to favour the desired species.

This series of investigations is one of the most detailed and able which has been carried out in recent years; the author has spared neither time nor energy in obtaining extensive data and information; his conclusions, tempered with restraint, are valuable. This excellent publication is strongly recommended to those who are interested in the femel-coupe system, which has its obvious advantages for future use in this country, to those who are concerned with silviculture and forest management, and finally to those working on light intensity, precipitations, and other forest influences.

W. B. R. Laidlaw. *Guide to British Hardwoods.* Leonard Hill (Books) Ltd., London, 1960. Pp. 250. 123 composite line drawings comprising about 500 separate items. Price 30*s.* net.

Review by H. L. Edlin

BOOKS on British trees are so numerous that any new-comer must show some peculiar merit or originality before a reviewer can commend it to his public. Dr. Laidlaw's strong point is his comprehensive set of botanical drawings of leaf, flower, and twig details, which are as good as any yet published. In a few instances his publishers, constrained no doubt by economy, have reduced the originals too far, so that some of the artist's meticulous work has been sadly blurred—the alder on page 155 is an example; but on the whole the reproductions are satisfactory. Less happy is the inclusion on certain drawings of reference

letters that are nowhere explained; for example, in fig. 84 we are told what 'P' and 'b' are, but are given no clues to α and β. Still less fortunate is the absence of any indication of scale on any of the drawings. Occasionally we are told that a feature is 'enlarged', but never by how many times! Worse still, nothing is said about those occasions on which features have been presented not at natural size, but very considerably reduced. These are faults in presentation, rather than in drawing, and could well be remedied when the work is reprinted. There are no illustrations of individual trees, nor of tree seedlings.

The text is mainly composed of keys, classifications, and botanical descriptions. Only brief notes on forestry or timber values of the trees are given. Hence this is more a botanical textbook than a guide to the practising forester. There are three conventional keys, to 'Winter Twigs', 'Summer Characters', and 'Fruits', and much painstaking work has gone into their construction. Frankly, nobody with the excellent set of drawings to look at, at one end of this book, is going to spend much time struggling through the involved keys at the other; but the close descriptions will clear up many doubts or questionable identifications. Two novel features are a tabular key to the 'General Field Characters' of each tree as a whole, and a tabular 'Seasonal History', showing when each tree comes into leaf, flowers, ripens its fruit, and sheds its foliage, using the Edinburgh district as a standard locality for assessment.

Concentration on botanical features aiding identification makes this a book of restricted value to the general reader, seeking to know his trees in broader terms. But much material is presented here better than elsewhere, and the book well merits a place on the bookshelves of both teachers and students of forestry. All native hardwoods are included, with a reasonable selection of the commoner introduced kinds.

WILLIAM A. DUERR. *Fundamentals of Forestry Economics*. McGraw-Hill Book Company, London, 95 Farringdon Street, E.C. 4. 1960. Pp. 578. Price 74*s*.

Review by A. J. GRAYSON

FOLLOWING hard on the heels of A. C. Worrell's *Economics of American Forestry* (John Wiley, 1959) this new work of Professor Duerr's marks a most important addition to forestry literature. His coverage of the subject is most comprehensive; so much so that this book may be said to surpass all previous forest economics works in the English language (and indeed so far as one can judge in any language) which have attempted to bring together in one text fundamental economic principles and instances of their application to problems of forestry economics.

The author tells us that before publication much of this work was discussed and criticized over several years, and the benefits it has thus acquired show themselves in the breadth of the subject-matter handled and the well-planned interweaving of principle with example (most of the illustrations are drawn from American forestry, but only in the sections on institutions in forestry can this feature be held to limit the general reader's interest). While this is a readable book, its length, as befits a textbook, may mean that it will deter the less ardent student. It may well be that there is still a place for a shorter publication indicating the importance of the questions handled by forest economists, the contributions that may be made to forestry planning and management, and the type of research necessary to achieve these ends. But in the absence of any such guide, this book with its pithy chapter summaries may be unconditionally recommended to all practising foresters and teachers of forestry. Many foresters will be glad to find no mathematics beyond arithmetical manipulation is called for in reading and understanding the book. At the risk of irritating

readers already versed in economic theory, the author has made things easier for others who have had no previous acquaintance with the subject by dealing fairly fully with certain purely economic matters in the course of developing analyses in forest economics. Because of this, the text is necessarily lengthened a good deal, but the treatment is at least successful in averting any criticism that might otherwise be levelled on the score of lack of terminological definition or absence of sufficient ground preparation.

Through his connexion with U.S. Forest Service and his position as Professor of Forestry Economics at Syracuse, Dr. Duerr combines experience in both economic research and teaching. Extracts from his first and final chapters may be quoted to demonstrate his straightforward approach. 'Forestry economics considers how forest lands and related human and industrial resources are allocated, or managed, to help satisfy people's wants. It considers the question from two points of view: first, that of the witness trying to describe, and if possible explain, human behaviour; second that of the consultant offering guides to social or individual policy' (p. 10). In listing some final issues that the reader will wish to consider (p. 563), he enjoins us to 'Bear in mind that the economic problems of forestry are not the forest's problems nor the mill's, nor those of the system: they are people's problems.'

The book is arranged in five parts. After an introductory section in Part 1 dealing with resources of the forest economy and a discussion on society and the individual, attention is centred in Part 2 on the individual firm as the unit of economic activity. Here the marginal analysis is illustrated with increasing degrees of complexity by reference to the production characteristics of a firm undertaking 'release cutting' work using one or several forms of labour input. Passing on to the discussion of other factors of production, the author considers forest capital and interest. Chapter 8 points out the great utility in forestry (or for that matter any other productive activity) of posing the question 'What are the alternatives?' The problem of deciding the optimum level of growing stock in even-aged stands (largely a matter of rotation choice) is comprehensively treated, though by a somewhat laborious method. This arises mainly because a detailed arithmetical exposition while leading finally to the desired result, lacks the elegance of the approach to financial maturity achieved through the use of differential calculus. This method is illustrated in a joint paper by the author and Fedkiw and Guttenberg (*Financial Maturity: a guide to profitable timber-growing:* U.S.D.A. Technical Bulletin No. 1146, August 1956).

His discussion of desirable thinning treatments is disappointingly scant, and perhaps rather one-sided in its concentration on thinning effects on the crop in the short term. The essential point in questions of rotation length and thinning régime is, however, made clear, namely that the best combination depends not only upon the forest, but also upon the owner (p. 136). Here the alternative rate of return (namely the rate of interest determined by the firm's best alternative uses for its funds) becomes involved, and in chapter 10 the interaction of interest and conservation are discussed in an enlightening way. Professor Duerr clearly demonstrates (p. 159) that the alternative rate of return, or guiding rate of interest, is a principal index of managment. In chapter 11, land use is treated in an interesting manner by stressing the influence of transport costs (as modified by the effects of the lands' inherent productivity as well as by institutional factors) in sorting out the uses of land within a region. The siting of manufacturing plant in relation to raw materials and markets for processed goods is also covered.

The subject of the supply of processed products is taken up in chapter 13 and the supply of standing timber discussed in chapter 14. Both these chapters are of special interest since they make good some noteworthy gaps in forest economics writing. These later chapters of Part 2 link with the opening chapter of Part 3 on the demand for forest products to provide

an analysis of the market for these goods. The use of indifference curve analysis makes the derivation of demand curves appear simple; notions of derived demand and of price and income elasticities are neatly introduced. Subsequent chapters relate to functions in marketing, the agencies carrying them out, and the siting of markets. A final chapter in this important section of the book deals with possible appraisal methods for services which are not exchanged in the open market (e.g. recreation).

Part 4 on institutions is of interest and concern primarily to American readers since it deals with the particular circumstances of centres of influence (in management and labour), tenure, tax, credit and insurance found in the United States.

In Part 5, operation and planning of the forest economy is the central theme. The chapters here, taken in conjunction with chapters 15 (management planning for the firm), 16 (methods of economic planning), and 22 (marketing agencies and their practices, where practices are traced in their various manifestations through the history of use of the timber resource in the United States), provide an absorbing interpretation of the history of forest resource use. They also indicate the kind of planning needed to equate demand with supply in the future. Social planning in the widest sense, planning public forestry measures and planning for a specific land area are covered in the final chapters. These discussions are the ones that deserve attention from policy makers, whether they be forest managers in private or government service, or land-use planners (armchair or otherwise). All foresters would do well to read these chapters which are full of relevance to British conditions at the present time.

H. L. Edlin. *Wild Life of Wood and Forest.* Hutchinson & Co., Great Portland Street, London, W. 1. 1960. Pp. 208 with 39 plates and index. Price 25*s.* net.

Review by Monica Vizoso

MR. EDLIN is already well known as an author and editor of books on many aspects of forestry. In this volume he reviews more than a hundred mammals, birds, amphibians, and reptiles associated with woodland habitats. Both common and latin names are given, the animals are briefly described, and there is information on their feeding, breeding, home-making, and movements. Particular emphasis is given to those habits which may bring the animal to the attention of the forester, and the author is careful to stress that a species guilty of causing harm to crops may yet be an asset in other ways. The book begins with a thoughtful introduction, and is pleasantly illustrated and remarkably free from misprints. There is an index of common and latin names, but no bibliography.

In addition to the chapters on wild species and game birds, there is one dealing with farm stock on free range: an influence in forest history which is sometimes overlooked. Stressing that cattle are woodland beasts by nature, the author describes how bullocks are used to reduce fire hazards in some northern spruce woods. The blue moor grass, *Molinia caerulea*, withers to a paper-thin inflammable straw if left in the rides, and the cattle are therefore allowed to graze the summer growth.

Some misleading statements need correction. Rabbits in Britain were first affected by myxomatosis in October 1953, not in 1954: and it is surely unrealistic to lay the blame at the feet of migratory birds? It is generally agreed that the average litter size for both red and grey squirrels is three, not 'only four or five young'; and in normal years grey squirrel births are most frequent in March and July rather than in March and August. The years 1950–7, described here as a favourable period for the grey squirrel, included

one of the most unfavourable years (1955) in the history of this species in Britain. More evidence would be welcomed to support the views that red squirrels were native in Ireland before 1700, and that dormice have become scarce as a result of competition with grey squirrels. The reader is led to assume that red lead is applied to seeds in the belief that mice have colour vision. In the section on stoats, nothing is said of the delayed implantation which is a feature of their breeding cycle; instead of mating in February and giving birth in May, as stated here, the stoat mates in June or July and bears young the following April; and the marten is suspected of having the same type of breeding pattern. White stoats have been reported at times in southern counties of England, so that it is unwise to deny that this colour change occurs in the south. Finally, *Martes foina*, the beech marten, is a distinct species, and not a 'local continental race' of the pine marten, *Martes martes martes*.

More facts would have been welcome on the subjects of bounty payments and their success in forests, the assessment of damage, and on the mortality of young animals and the significance of this for some species. Nothing is said of the effect on wild life of insecticidal sprays or other chemical treatments applied by forester or neighbouring farmer. Plates 7 and 11 deserve honourable retirement.

Mr. Edlin is one of the few people who have seen, at close quarters, the woodcock carrying its young in flight. His personal field observations in a wide variety of forest conditions add to the value of the text. The forester may find that local naturalists and neighbours who read *Wild Life of Wood and Forest* come to understand his responsibilities more fully, and with even greater sympathy.

STEPHEN H. SPURR, *Photogrammetry and Photo-Interpretation*; with a section on Applications to Forestry. Second edition of *Aerial Photographs in Forestry*. The Ronald Press Company, New York 10, N.Y., 1960. 9¼ × 6¼ inches. 472 pp. illustrated. Price $12.00.

Review by F. C. OSMASTON

MOST foresters today acknowledge the value of aerial photographs as an aid to forest management. The wealth of recently published literature, particularly with reference to extensive forestry, both testifies to this recognized value and reflects the technical difficulties that have to be surmounted and understood before aerial photographs can be used with sufficient accuracy. This work by Stephen H. Spurr is, therefore, very welcome. In one book the fields of photogrammetry and interpretation are described in considerable detail with many explanatory photographs and supported by a very full bibliography. The reader can therefore learn the theory and possibilities of aerial photography so that with the practice essential for success he can master this comparatively new aid.

Although a second edition, the new title is fully justified by the enlargement and reorganization of the new text which has been largely rewritten and illustrated by even more diagrams and photographs. The first half of the book (in three parts) covers the theories that support the science of photogrammetry, their practical application, and the business of mapping. These essential chapters enable the reader not only to understand the 'jargon' of photogrammetry but also the effect of camera focal lengths and flying height on scale and degree of displacement of objects as well as the phenomenon of stereoscopy and consequent methods of, and devices for, measuring heights and overcoming displacement by radial line plotting. In short a full but concise account of theory, instruments, and methods used in photogrammetry is given.

Foresters may be more interested in the second part of the book in which the application of the theories and practice of mapping and interpretation are applied to forestry. Here foresters will be more critical. They may admit the value of aerial photographs for mapping and record of facts, the display of existing land use and changes in that use from time to time. They may question whether aerial photographs can provide sufficiently accurate distinctions for delineation of species, age classes and site types or dimensions accurate enough to give useful estimates of timber volumes, particularly for broad-leaved species. Even if all this is possible, is it economically justifiable for the comparatively small accessible forests of Britain?

The sceptics should read Spurr's book. He describes well the value of aerial photographs for interpretation of geology, soils, and vegetation. Although the book is written primarily for the American reader and the majority of the factors relating to the interpretation of forest types and other vegetation refer to conditions in the U.S.A., many references to work done elsewhere, including the tropics, are given. An interesting example of this is in the diagrams that illustrate changes in reflectance of species such as oak, beech, birch, spruce, and pine during the months of May and June showing that the greatest difference in reflectance percent. is in May when identification should be proportionately easier.

Two chapters and 142 pages are devoted to the measurement of trees and stands and the estimate of diameters and volumes. Methods and techniques are fully described with examples of tree aerial volume tables and stand volume tables and a discussion of accuracy. Although the possibilities of aerial survey in conjunction with ground enumeration are great in extensive forestry and displayed convincingly, one is still left doubtful whether such advantages would occur in the small, generally accessible forests of Europe, while the technical difficulties in tropical forests are considerable. But one is convinced that much more research work in both European and tropical forests is desirable. The book is clearly and generally concisely written although in the last chapter on forest management, which is the weakest and, in places, seems to extol the virtues and potential value of aerial photographs too highly, there is exact repetition of two paragraphs of an earlier chapter. The book contains a wealth of information and ably summarizes the state of existing knowledge, technology, and experience in this valuable forestry aid. Notwithstanding his obvious enthusiasm for the use of aerial photographs, the author never fails to stress the essential importance of ground work and intimate field knowledge of the forest.

P. P. Pirone. *Tree Maintenance.* 3rd edition, 1959. Oxford University Press. Pp. 483, illustrated. Price 70s. net.

Review by R. H. Hide

THIS book was originally published in 1941 as *Maintenance of Shade and Ornamental Trees*, and revised in 1948. A corrected and enlarged edition has now been published by Dr. Pirone who has been Plant Pathologist at the New York Botanic Garden since 1947 and is consultant for the New York City government and also landscape maintenance consultant for the United Nations headquarters in New York. In his preface the author states that he has tried to incorporate his wide experience of tree maintenance problems of the past twenty years and to follow a course midway between the technical and the popular.

The first part of the book (150 pages) is headed 'General Maintenance Practices', and this, after a brief introduction describing a tree in simple terms and its relation to soil and habitat, goes on to deal with the modern arboricultural practices current in America.

There are chapters on Transplanting, Fertilizers, Pruning and Treating Wounds, Cavity Treatments, Bracing and Cabling. There is a final chapter in this section on 'Trees suitable for various locations', and this naturally concerns itself with American conditions.

The second part of the book (278 pages) is headed 'Diagnosing tree troubles' and is aimed at helping 'arborists, city park departments, public utility companies and private home owners to diagnose causes of decline and death in their ornamental trees.' After a brief outline of examination methods and tools there are chapters covering Non-parasitic injuries, Insect Control, Spraying Equipment, Tree diseases and their control, General Parasitic Diseases, and then three final chapters on the Diseases and Insect pests of (*a*) Low-growing trees, (*b*) Tall-growing trees, and (*c*) Evergreen trees. The trees in these sections are listed alphabetically by their popular names and the brief descriptions of the diseases or insect pests are followed by suggestions for control.

There is an interesting appendix on a method of valuing ornamental trees and a classification of ornamental trees into seven regions by botanical name and popular equivalent. This is followed by 19 pages of a bibliography arranged under the several chapter headings and finally by 16 pages of index.

This is an American book and its aim is admittedly popular. The field it covers is wide, reaching from Texas to Canada. It is written clearly and in a straightforward manner and the illustrations are an excellent support to the text. British arboriculturists may take a moment to equate 'Shoestring rot' with their more familiar 'Honey fungus' but latin botanical names are always given and the indexing is good. The book will be looked on as an up-to-date and well-illustrated description of current American arboricultural methods and practices. As the book is directed at an American public the large bibliography is almost confined to American and Canadian literature. One unexpected spelling error is found in A. D. C. Le Sueur's name in this bibliography.

J. W. L. Zehetmayr. *Afforestation of Upland Heaths.* Forestry Commission Bulletin No. 32, H.M.S.O., 1960. Price 17*s.* 6*d.*

Review by H. M. Steven

THIS long-awaited publication will be warmly welcomed by a wide circle of foresters at home and abroad. Two of the major advances in forestry in Britain during the past forty years have been in devising techniques for the successful afforestation of heaths and of peat moorlands. We now have bulletins on both these subjects by the same author,[1] and Zehetmayr is to be congratulated on presenting so concisely and lucidly the vast amount of experimental work carried out by the Research Branch of the Forestry Commission.

The present bulletin is divided into twelve chapters: The characteristics of upland heaths; comparison with other European heaths; the experimental areas; preparation of ground by hand; ploughing; the main species used; the less widely used species; manuring; nurse crops and mixtures; stimulation of checked plantations; trial plantations; and miscellaneous experiments.

For the purposes of the bulletin, upland heaths are defined as follows: 'Heather-clad land, on strongly podsolised very compact soils, with a thin layer of humus, and typically a thin iron pan, . . . at altitudes over 500 feet.' There is no general ecological discussion of these communities, but particulars of the different heath communities listed by the late Dr. G. K. Fraser at Clashindarroch and adjoining forests are given. The bulletin was prepared before the

[1] The earlier bulletin is Forestry Commission Bulletin No. 22, *Experiments in tree planting on peat* (1954).

recent publication on *Calluna vulgaris* by Dr. Charles Gimingham in the Biological Flora of the British Isles. In discussing the soils, the author follows mainly the earlier work by Muir at Teindland and by Jacks at Allerston. The important differences between normal podsols on the one hand, and peaty podsols and peaty gley podsols on the other are noted. The last two, typical of British upland heaths, and usually with a more or less continuous iron pan, are very different from normal podsols, typically associated with the Northern Coniferous Forest, and there has been confusion in thought and deduction from a failure to realize this. Duchaufour has recently emphasized the differences pedologically, but this was probably after the bulletin was prepared.

In chapter 2 there is a description of afforestation of heaths in Jutland, Schleswig, and Holland, and the author discusses its relevance to conditions in Britain. As regards techniques, there has been on the whole more thorough cultivation on the Continent than in Britain where some type of single-furrow ploughing has been considered sufficient for successful establishment, but, in the opinion of the reviewer, it cannot be considered as yet proved that such crops will prove stable against wind; this will be referred to later. In view of the importance attributed by some to broadleaved 'soil improvers', it is interesting that the author mentions the recent action of the Dutch in cutting out red oak in some woods because it was smothering other species in mixture. There is a brief description of regeneration practices in heath woodlands, particularly in Jutland, which may have some relevance to this country in due course.

Cultivation is basic to successful afforestation of heaths, and chapters 4 and 5 deal with hand and plough cultivation respectively. The author has ably summarized the results of the many experiments which have been carried out. There is a good discussion of the function of ploughing on upland heaths in the light of present evidence, and the results obtained by Yeatman (*Tree Root Development on Upland Heaths*, F. C. Bulletin No. 21) are assimilated. It is noted that one objection to single-furrow ploughing is that the main roots are usually orientated in the direction of the ploughing, but this is not so on completely ploughed areas. This has been broadly confirmed by work done recently at Aberdeen on a wider range of ploughing methods. Zehetmayr rightly regards this as undesirable from the point of view of stability against wind, but takes some comfort from the fact that young crops at least escaped damage in the catastrophic gale on 31st January, 1953. It may be mentioned, however, that a gale in October 1959 caused considerable windthrow of young trees in some heath plantations in the north-east of Scotland which were ploughed according to the current technique, namely shallow mould-board with a deep subsoiling-tine.

Chapters 6 and 7 on the major and the less commonly used species on heaths contains much interesting data, including some provisional estimates of volume production, together with well-judged evaluations. Many will be surprised at the large number of species used experimentally—almost sixty. It is concluded that while Lodgepole pine on the poorer heaths, and Japanese larch with good cultivation and manuring may grow faster initially, Scots pine is likely to prove the most suitable species for first generation crops on many sites. More shade-bearing species, such as Western hemlock, may prove valuable later on for underplanting and the succeeding generations of woodlands. The role of Sitka spruce is likely to be more limited than was once thought, even in mixture with pines and Japanese larch. Most heaths are in regions of only moderate rainfall or less, ploughing has made even the moist heaths drier, and transpiration losses will increase, hence it is unlikely that species with relatively higher water requirements will do well.

The extensive work on manuring led to the conclusion that: 'Phosphate has a more limited part to play in establishment on heaths than on peatlands, and in particular that it can be used to compensate to some extent for less intensive ground preparation or for

planting stock below normal size or quality.' An initial dose of 1½ to 2 ounces of ground mineral phosphate per plant only costs about £3 per acre for fertilizer, labour, and overheads, and it increases early growth on heaths in general and is necessary on the poorer, especially in Scotland. What will be the long-term benefit remains to be seen. The application of NPK has not so far proved worthwhile compared with phosphate alone. Time will show whether further and complete manuring will be necessary to maintain growth to a suitable utilizable size of tree in the first rotation, and still more in successive rotations.

There is an interesting chapter on nurse crops and mixtures; many of the experiments deal with species chosen to bring on Sitka spruce. There have been difficulties in handling these, with nurse crops suppressing the desired species, but one has different means of controlling species, such as choosing particular strains, for example in *Pinus contorta*, differential methods of cultivation and manuring, and also different espacement patterns; in recent years three row mixtures have been popular. The use of broom as a nurse for the more exacting species has generally been successful; it is, however, a costly method for large scale application.

The bulletin concludes with a brief account of experiments designed to stimulate checked plantations of spruces, such as heather removal, mulching, manuring, &c., a short account of some so-called trial plantations, and some miscellaneous experiments.

There is a good summary and a selective bibliography. The illustrations are well chosen to show sites and some of the ploughing equipment; some of the latter will no doubt interest or amuse our successors.

E. R. Huggard and T. H. Owen. *Forest Tools and Instruments.* A. and C. Black, 4–6 Soho Square London W.1, 1960, with 44 illustrations. Price 18*s.* net.

Review by A. H. Lloyd

THIS is the third publication during the past four years from the Department of Forestry, University College of North Wales, dealing with forest engineering and utilization. Mr. Huggard's first book *Forest Roads* was followed by a joint publication, with Mr. Owen, *Forest Machinery* (both reviewed in *Forestry* xxxii) and the present book completes the series which will be found very useful by forestry students and by others.

The present volume covers a wide range of tools and instruments from axes and saws to drawing instruments and stereoscopes. All the tools and equipment are well illustrated from over forty different manufacturer's photographs. Detailed descriptions of the uses and methods of operation are given for each item and also its application to forestry.

The authors anticipate a fairly rapid and widespread mechanization of forestry operations and assume that the chain saw is now reducing the importance of the axe and the felling saw. This is certainly so in Great Britain and in similar countries where labour costs are very high, but it is not yet evident in densely populated tropical countries such as Africa and the East where the axe and saw (including the pit saw which is omitted altogether from this book) seem likely to remain most important forestry tools for many years to come. Amongst other tools, twelve different types of spades and shovels are illustrated and discussed.

Tree-measuring instruments discussed include hypsometers, the Haga altimeter, the dendrometer, and the Spiegel Relascope (*Forestry*, xxx. 173). The Brandis hypsometer is included in these tree-measuring instruments but is, of course, now being superseded by equally accurate instruments which eliminate the tiresome mathematical tables required with the Brandis.

Surveying instruments include the aneroid barometer, which is well described with appropriate warnings of its inaccuracy and limitations.

A section dealing with extraction and utilization equipment includes the uses of block and tackle, chains and slings, dynamometers for checking the performance of tractors, and also metal detectors with transistors for finding suspected metal in big logs. Extraction tools include timber tongs, canthooks, pievies, chokers, and pulp hooks, which are all illustrated. A useful page on the selection and care of wire ropes and cables is followed by instruction in the uses of pulleys and sheave blocks.

Various meteorological instruments are described, including anemometers, barometers, rain gauges, and hygrometers. A final chapter on office equipment includes the uses of a pantograph and a new 'sketchmaster'.

This is an extremely useful work of reference but is not intended to provide light reading for a winter evening.

W. A. FAIRBAIRN. 'Climatic Zonation in England and Wales', *Int. Journ. of Bioclimatology and Biometerology*, vol. iv, part 2. Leiden, 1960

Review by R. F. WOOD

DR. FAIRBAIRN has now followed the Climatic Zonation of Scotland, in which he was associated with Prof. M. L. Anderson, by a study on similar lines for England and Wales. It is greatly to be hoped that this will be published in a form which will be readily available, for there can be no doubt that many people will be interested.

Dr. Fairbairn has used the scheme applied in the Scottish zonation, and hence the two studies are complementary. His zonation is based on the length of the growing season above 45° F., and the growing season rainfall (April–September inclusive); the former serving as the principal division of the country, which is further subdivided by rainfall to sub-zones. On this basis he has recognized fifteen climatic types, which, since some recur in different regions, give in all thirty-three divisions. These are set out in colour on a map to the scale of fifty miles to the inch. Outline maps are also given for length of growing season and growing season rainfall, and a map dividing the country into five 'exposure zones' is also provided. Appendixes give additional climatic data for the zones, geological notes, and brief comments on land usage or silvicultural importance of the climatic sub-zones. In the main text (which is approximately 7,000 words in length) there is a full discussion of the climatic features of the country and argument in support of the indices which have been adopted in this particular classification. A short bibliography is provided.

It will plainly require a good deal of study to decide how far this particular classification is likely to prove helpful in practice, but a few points can be made about the approach. There is not much doubt that classification of growing conditions should be based on the supply of heat and moisture; any scheme which divides the range of any measure of each of these two factors, and puts the two things together in a compound classification, is bound to produce a picture of the climate which has some meaning. The principal trends will be illustrated, and this is certainly useful since it teaches people to think more clearly about the 'shape' of our climate than they do when looking at maps of single variables. The pictures will vary according to the measures of heat and moisture adopted, and also with the choice of classes. This latter point is well illustrated by comparing Melvyn Howe's 'Climatic Sub-Regions of Wales' (see page 80 in this issue) with Dr. Fairbairn's map. Melvyn Howe has followed the same scheme of classification, but his intervals for both rainfall and growing season length are slightly different. The resulting maps differ quite considerably, though they are clearly of the same general pattern.

If a classification of this sort is to do more than divide up the country into arbitrary

provinces, it may either attempt to demarcate 'natural' boundaries (such as the limits of some ecological type, or the useful range of some tree), or it may aim at a rational relationship between the two principal supply factors of heat and moisture. To succeed in the former would entail a very detailed investigation into the responses of tree growth to the various climatic factors, and it is fairly certain that the result would be complex, since it is clear that our principal tree species are responding differently to our trends of climate. It is noticeable, for instance, that certain species improve as the climate becomes more oceanic, whilst others decline. Others again may not be particularly sensitive to this trend. On the whole one feels that the second approach might be the more useful at this stage of our knowledge, though it is less ambitious. The simplest form, it is suggested, is a map of potential evaporation (itself a fair measure of energy), further subdivided by isohyets of growing season rainfall. One of the attractions of such a map would be the provision of a link between the local soils survey and the regional climate, since it would enable one to think of the soil storage capacity in terms of the normal summer deficit. This may seem a trifle fanciful, but the connexion of local factors and regional climate is a practical problem for any forester who is concerned with very different environments.

Dr. Fairbairn discusses evaporation as a climatic variable and stresses its importance in relation to rainfall especially in the drier parts of the country. However, he feels unable to use it in his scheme of classification owing to the shortage of measured values. This does seem to be a pity, for the introduction of evaporation is the only means of giving other than arbitrary values to precipitation. Dr. Fairbairn gives four classes for summer rainfall, under 12 in.; 12–15 in.; 15–30 in.; and over 30 in. These he applies to each growing season zone. It would have been preferable to have made some distinction between the precipitation classes for the different temperature zones, though this would have been rather arbitrary. A more serious objection might be that the classification becomes rather coarse in the third class where there may be either deficiency of summer rainfall below evaporation or a very considerable surplus. Penman's (1950) map of evaporation could no doubt now be reinforced with a number of more recent calculations, and it is felt that this ought to be the basis for evaluating rainfall.

Dr. Fairbairn's arguments for using the length of the growing season (over 45° F.) as a measure of warmth are not particularly convincing. Undoubtedly the length of the growing season is of importance to many plants, but its adoption as a primary division seems to introduce too much bias in favour of any highly oceanic south-western climates as against the slightly more continental ones. Many of our trees do not respond to this trend in climate, but appear content to utilize their ration of heat over a shorter growing season. Dr. Fairbairn has three growing season zones south of a line Wash–Severn estuary, increasing from east to west, out of the five he uses for England and Wales as a whole. It is interesting to compare this with Gregory's (1954) map of accumulated temperature, which places all this area substantially in one category (2,500–3,000 day-degrees F.), with the exception of a few coastal pockets at 3,000 day-degrees. For many purposes this might well be adequate. Ideally, no doubt, one would like to deal with the amount of heat and the temperature régime separately.

Though Dr. Fairbairn's claims for his classification are modest, the preparation of a climatic zonation for the country is an ambitious undertaking. Foresters will be much beholden to Dr. Fairbairn for making the attempt.

LITERATURE REFERENCES

Gregory, S. (1954): 'Accumulated Temperature Maps of the British Isles.' *Inst. Brit. Geog. Trans. and Papers.* Publication No. 20.

Penman, H. L. (1950): 'Evaporation over the British Isles.' *Quart. J.R. met. Soc.* lxxvi. 372–83.

T. R. Peace. *The status and development of elm disease in Britain.* Forestry Commission Bulletin No. 33. H.M.S.O., 1960. Pp. iv+44 with 18 figs., 12 tables, and 76 plates. Price 10*s*. net.

Review by R. H. Richens

FEW plant diseases have brought themselves so forcibly to the notice of the general public as the elm disease caused by the fungus now usually referred to as *Ceratocystis ulmi*. So dramatic were some of its early ravages in this country that elm has largely disappeared from the lists of species recommended for future growing. To what extent this consternation was and is justified is assessed in Mr. Peace's bulletin and the data and conclusions of this publication deserve most careful study by anyone concerned with tree-raising policies in general, in addition to those more specially interested in the elm or in the pathology of forest trees.

It is seldom that one research worker can claim so long and intimate acquaintance with a problem as Mr. Peace can with the elm disease. The first discovery of the disease in this country was at Totteridge, Hertfordshire, in 1927. In 1928 Mr. Peace began a study of the incidence of the disease on behalf of the Forestry Commission and has been able to keep a close eye on it ever since. The present bulletin is largely devoted to describing the course of the disease in this country as revealed by repeated surveys and to framing recommendations, on the basis of what has been discovered here and elsewhere, on control measures and elm-growing policy.

The bulletin consists of seven chapters. The first deals briefly with symptoms of the disease and the characteristics of the fungal pathogen. Responsibility for transmission is fixed definitely on the two bark-boring beetles *Scolytus scolytus* and *S. multistriatus*. This at once explains some features of the distribution of the disease since *S. multistriatus* is essentially a southern insect and *S. scolytus* only just reaches Scotland and in fact was not recorded for Scotland till searched for in the course of the disease surveys.

In chapter 2 the history of the spread of the disease in Europe since its first record in France in 1918 is recounted, followed by a description of its local progress in Great Britain. Where the pathogen is native is still unknown though eastern Asia is suspected. It is thought probable that the disease was present in this country some time before recognition, rings showing infection for 1912 having been discovered in a tree at Kettering. Somewhat ironically, other species besides elms suffered in the initial Totteridge outbreak and it is possible that the elm disease was only secondary to a gas leak.

The third chapter deals briefly with other elm diseases and it is well to bear in mind that phloem necrosis, a virus disease at present confined to North America, is more serious there than the subject of this bulletin.

Variation in pathogen and host are considered in chapter 4. The fungus varies considerably in culture but there is no evidence that this variation has any importance in determining behaviour in the field. As is well known, the elm is highly variable in this country and up to seven species have been recognized. Mr. Peace admits that difficulties in identification led to abandonment of any serious attempt to obtain data on specific or varietal resistance. It seems, however, that no really resistant kind occurs in Great Britain and the only species worth while using in breeding for resistance are the Central Asiatic and Far Eastern species *Ulmus pumila* and the Himalayan species *U. wallichiana*. Breeding work for resistance is principally proceeding in Holland though the two resistant varieties bred there, Christine Buisman and Bea Schwarz, have drawbacks which render them unsuitable for general introduction. The present Dutch projects for hybridizing European elms with recently collected material of *U. wallichiana* will be watched with great interest.

The longest chapter is the fifth, where the findings of the annual surveys are set out in detail. This chapter, supplemented by a fine set of photographs showing the progress of the disease in selected trees in successive years, is of the greatest importance since it brings out clearly that the disease rose to a peak around 1936–37 and then declined, and that, though almost universally present now, seems no longer to be a matter of major concern. Many trees heavily infected in the past have since recovered, mainly, it seems, due to failure of the fungus to cross from one annual ring to the next. The reasons for the overall decline are however, still obscure. Mr. Peace discusses various theories and rejects those that suppose either an increase in resistance of the elm due to selective elimination of highly susceptible genotypes or attenuation in virulence of the pathogen; he prefers a solution proposed by Mr. J. Macdonald who would attribute the decline to the prompt removal of dead elm timber during the war and in subsequent years and hence in a reduction in sites for *Scolytus* breeding.

We thus arrive at the last two chapters on control and conclusions. There have been two major views on control: wholesale felling and *laissez-faire*, the former represented by the Dutch and the latter, unsurprisingly, by the British. There is no unanimity, in the light of knowledge now gained, as to what course should have been pursued. The Dutch are reputed to have lost two-thirds of their elms by their felling policy and the author clearly doubts, in the light of his experience in this country, whether this was necessary. The situation in Holland is, however, not exactly comparable with that in Great Britain since, in contrast to the extreme variability of the elm in England, the Dutch plantings are largely monoclonal of the very susceptible var. *belgica*. The author's conclusions therefore are in effect a vindication of the policy of *laissez-faire* which, though doubtless deriving its main support from national habit, is clearly shown to have been vindicated by the event. Mr. Peace mentions the devastation caused by the disease along the Essex–Hertfordshire border; the disease is still present but elm is again a major component of the landscape. Other methods of control, such as spraying against *Scolytus* and use of systemic fungicides, to which biological control could have been added, are rejected as either ineffective or uneconomic, and the general conclusion emerges that, except for formal avenues, where a single loss can spoil the overall effect, the hedgerow elm can and should retain its place in the English countryside.

T. Vedel and J. Lange. *Trees and Bushes in Wood and Hedgerow*. Translated from the Danish by C. H. R. Hillman and adapted by H. L. Edlin. Pp. 224 with 96 pp. of coloured illustrations; numerous sketches interspersed throughout the text; diagrams and maps. Methuen & Co. Ltd., London, 36 Essex Street, W.C. 2, 1960. Price 16*s*. net.

Review by M. Penistan

THIS is a Danish work whose artistic merits enhance, almost to the point of distraction, the careful assembly of facts. The book, which is really in two main parts, is arranged for easy reference. Nearly the whole of it is taken up with an identification key, over one hundred illustrations of the species, and descriptions of these trees and bushes, where nomenclature, botanical description, biology, habitat, and utilization are dealt with. There are maps which show geographical distribution. Other sections, which take up only eighteen pages, deal with wood structure, development of British forests, tree breeding, great trees, as well as glossaries, Latin-English and botanical, and an index.

This book which has been translated by C. H. R. Hillman and adapted by H. L. Edlin is notable for its popular appeal. The days when Bentham and Hooker was diligently coloured

by botanically minded ladies with time to spare has passed and *Trees and Bushes* answers the present demand for colour and visual aid to learning. A note on the keys helps beginners, leaf in hand, to take the first steps towards identification. When they reach the plates in colour they will almost certainly be diverted and captivated by among other things the crescent moon above the spruces, the bottle of gin beside the juniper, and the chequer board setting of the uses of beech; and on each page colour, colour, colour. The figures of people and animals, showing the scale, are quite charming though sometimes the habit of the tree is Danish rather than British. The main subjects hold their own, however, the varying shades of leaf, flower, berry, and bark texture being portrayed with surprising accuracy.

In his introduction Edlin says that the 'aim of *Trees and Bushes* is to describe the appearance of *all* the wild trees and shrubs found in Britain's open countryside', but this is made somewhat difficult by being a translation of a Danish book. It is possible that the translator and adapter were restricted by the Danish authors, but of forest trees there are omitted the Corsican pine and Serbian spruce (more generally used than white spruce in this country) while, though the park tree *Robinia* is illustrated, *Cedrus*, *Juglans*, *Cryptomeria*, and *Sequoia* are excluded. Of the several varieties of British elms only smooth-leaved and wych elm are described while the fluttering elm does not occur. This will tend to confuse the beginner and irritate the expert who, however, will be intrigued to check varieties such as *Myricaria*, *Amelanchier*, and bullace in his flora.

There has been some attempt to improve the scope of the book by adding at the end of the letterpress particulars of three common British shrubs not described in the original, but these, unfortunately, are not illustrated neither are they included in the identification key. The chapter on the trees' wood and nourishment is very good and easily understandable while the pollen diagrams illustrating the development of British forests bring this clearly to the layman in the wood almost for the first time. A careful examination will, however, show that the diagrams are, in fact, Danish and not British ones. The simple account of tree breeding is good and the list of big British trees stimulating to the amateur. It is noted that the index refers to the illustrations and not to the key as stated.

It is realized that it is always difficult to adapt a book from another language and country. The translation flows well and the book is worth while for its illustrations alone which go a long way to achieve the originators' wish to 'spread scientific knowledge of trees and shrubs among all who encounter them'. This timely and attractive publication should appeal to a British public at last showing some signs of interest in its forests. It should do a lot to bridge the gap between the twigs and conker school and the professional forester.

W. E. S. Mutch. *Financial and Cost Accounting for Forest Enterprises.* Bulletin of the Forestry Department, University of Edinburgh, No. 7, 1960. Price 7*s.* 6*d.*

Review by W. E. Hiley

THIS is a straightforward and detailed description of the methods which Dr. Mutch has used in keeping the accounts for the woodlands on the Bush and Dryden estates which belong to the Edinburgh Centre of Rural Economy. It is notoriously difficult for anyone who is not a professional accountant to bear in mind the numerous books which have to be kept, if even a small industrial unit is managed in such a way that the costs of individual operations can be worked out, but Dr. Mutch's elucidation is very elementary and even a beginner should be able to follow it if he studies it with reasonable care.

'The woodlands, 315 acres in 120 compartments, are principally shelter strips, former

amenity and sporting woods, and steep gorge sides unsuitable for agricultural use', and it appears that employment in the woods is less than half a man per 100 acres. It is not suggested that a complicated accounting system of this kind is appropriate for such a small venture, and it is clear that the method is used for the purpose of teaching rather than for ensuring profit.

My experience in the costing of woodland operations suggests that, although the work involved is very labourious, only a small proportion of the results which might be obtained from it is ever calculated. So it is desirable at the outset to limit the objectives to those which are most worth while and to reduce the number of entries as far as is reasonably possible. Dr. Mutch says that 'the object is to discover the profit or loss on each of the principal products and to establish the cost of individual operations', and a relatively simple costing system would be sufficient to throw up these amounts for the woods as a whole. It is far more complicated to work them out for each of the 120 compartments separately and the usefulness of doing so may be questioned. No examples are shown of the results which have been obtained and, though the methods adopted at Edinburgh could be made to yield very detailed costings, it is doubtful whether they would repay the trouble of getting them.

A further complication is added by a desire to express costs in terms of the man-hours employed, week by week, in each operation. This is rather unreal because a good woodman may do twice as much in one hour as a less competent worker. It is simpler to keep all costs in terms of money and to translate the results at the end of a year if it is desired to find the average number of man-hours used on each kind of work.

Such variations in objectives and methods are multifarious and interesting. They can only be studied when individual foresters have explained the way in which they keep their accounts, and we are greatly indebted to Dr. Mutch for explaining his methods in such detail that it is possible to compare them with the treatment adopted in other woods.

NOTICES

H. L. Edlin *et al. Cambrian Forests.* Forestry Commission Guide. H.M.S.O., 1959, iv+102 pp. Illustrated. Price 5*s.* net.

IT would be hard to find fault with this guide which has recently been added to the excellent series of guides issued by the Forestry Commission, a series which already includes guides to Argyll, Bedgebury, The Border, Coed y Brenin (in English), Dean Forest and Wye Valley, Glen More, Glen Trool, Hanes Coed y Brenin (in Welsh), Hardknott, New Forest, Queen Elizabeth Forest, and Snowdonia. It would be equally hard to suggest where any prospective visitor to Mid-Wales, forester or not, who was interested in the Welsh countryside and wished to get the 'feel' of it, could buy a better book for many times the money.

There is a foreword by Mr. Lloyd Owen while Mr. Edlin, who as usual edits the guide, writes also an introduction and a chapter on the Approaches to the Forests. The Forests are written up by Mr. W. A. Cadman; Agriculture by Mr. R. Phillips; Plant Life (admirably divided between intertidal regions, coastal strip, bogs, mines and quarries, woodlands, and lastly moorland and hill pastures) by Professor Lily Newton; Physical Features and Geology by Mr. John I. Platt; Mammals, Birds, Reptiles, Amphibians, and Fish by Mr. William Condry; and Insects by Mr. Best. There are chapters on The Old Mansions and their Woodlands by Mr. David Jenkins, Keeper of Printed Books, National Library of Wales and on Antiquaries and History by Professor Bowen. This is indeed a formidable team. There are two useful general maps of the area with the forests marked on them and also a geological map; there is a note on hotels, youth hostels, and Ordnance map sheet numbers and some beautiful photographs and pleasant wood-cuts. There is even a note on pronouncing Welsh names and the whole guide fits easily into the jacket pocket.

LESLIE WOLFF. *Science and the Forester*. London, G. Bell and Sons Ltd., 1960. Pp. 159. Illustrated. Price 15s. net.

A VAST amount of information, covering perhaps too wide a field, is contained in this book and the artifice of the author, who is Senior Lecturer in Biology, Newton Park College, Bath, of introducing it as the experiences of a young forester does not conceal the probability that the eight chapters are in fact the material of lectures to students and notes on visits to laboratories. It is none the less a good approach and makes the book acceptable to a larger public. It should awaken interest in the impact of science on a subject which is still too little understood and lead to further reading.

SIR SOLLY ZUCKERMAN, J. ENOCH POWELL, LORD PARKER, C. H. J. MALIEPAARD, P. A. STONE, and D. R. DENMAN. *Land Ownership and Resources*. Department of Estate Management, University of Cambridge and Cambridge University Estate Management Club, 1960. Pp. 136. Price 15s. net.

THIS book preserves in print the texts of a course of lectures given at Cambridge in the Summer of 1958. In the opening Chapter 'Purpose and Theme', Dr. Denman writes: 'The purpose in view was to focus attention on individual land proprietorship while setting it against the general background of national policy. This purpose could have been approached from a number of starting points. Two important committees, the Zuckerman Committee and the Franks Committee had recently published their opinions. Although what one had to say must have appeared to many people quite irrelevant to what the other was saying, the reports in fact struck a common note. One dealt with the best use of national resources from the national point of view, the other with the rights of the individual in a day of unprecedented State planning and administration. The reports of these committees provided more or less ready-made contributions to the general theme of the summer lectures.'

OBITUARY

C. P. ACKERS

Charles Penrhyn Ackers, O.B.E., of Huntley Manor, a very great forester, a prominent landowner, one of the Four Verderers of the Queen in the Forest of Dean, and a governor of the Royal Agricultural College, Cirencester, died in November 1960 in his late seventies.

Only a few days before his death he had been awarded the newly instituted gold medal of the Royal Forestry Society of England and Wales to be given 'as a recognition of outstanding services to forestry' and, by courtesy of the Society's President we give below the citation.

'Charles Penrhyn Ackers, O.B.E., was President of the Society from 1930 to 1932 and during a long life some of his main interests have been his woodlands in Gloucestershire, Montgomeryshire, and Selkirk, and his long-held appointment of Verderer of the Forest of Dean.

'When Mr. Ackers went to Armstrong College (now Durham University) there was no such thing as a Forestry Degree but he took an agricultural science course before going up to Oxford, and later returned to practical forestry in his father's woods at Huntley.

'From then on he busied himself with improving his woodlands and putting them on a sound economic basis. In 1938 his famous book *Practical British Forestry* was published. This book, now a standard work, is permeated with the two underlying principles which guided Mr. Ackers' work in forestry, firstly that estate forestry should be made to pay and, secondly, that it should aim to produce what the customers want.

'It was from the royalties on this book, so generously surrendered, that a fund was set up to provide prizes for an annual essay competition confined to post-war foresters and called the "Flying Officer R. D. Ackers Prize Essay Competition" in memory of his son. This fund also provides prizes for the best candidate in the annual Forester's Certificate examinations and bursaries to help foresters take part in foreign excursions run by the Society.

'After the war, with some help from the R.A.F. Benevolent Fund, Mr. Ackers started a forestry school at Huntley for ex-R.A.F. personnel who wished to take up forestry. Many well-known and successful foresters gained their grounding at this school.

'In 1958 he generously gave to the Society an area of woodland at Leighton on which stands the famous grove of redwoods now called the "Charles Ackers Redwood Grove".

'We honour Mr. Ackers as a generous friend of the Society and a great forester who passed on his extensive knowledge to the lasting benefit of those who followed him.'

The gold medal was received on his behalf at a ceremony in London in December when the Royal Forestry Society also presented their gold medal to three other distinguished English foresters, namely Lord Bolton, G. C. Wolryche-Whitmore, and W. E. Hiley.

Charles Ackers had long been a member of the Society of Foresters and served on the Council in 1951 and 1952. The last meeting that he attended was the discussion meeting at Northerwood in November 1959 and at which he spoke. The Society visited his estate at Huntley in October 1949 from Hereford, and some of us have done so many times since to our own great advantage. He will be much missed.

J. M. COWAN

Dr. John Macqueen Cowan, C.B.E., who died recently, entered the Indian Forest Service from Oxford and, in the next few years, he and his wife accumulated material which enabled them to revise Gamble's book on the trees of northern Bengal. He

collected then considerable botanical specimens in Sikkim, Bengal, and Burma. After the 1914 war he officiated for a short time as superintendent of the Royal Botanical Gardens at Sibpur, retiring in 1928 to a post at Kew. In 1929 with Dr. C. D. Darlington he was in Iraq and Persia on behalf of Kew and the John Innes Horticultural Institution mainly collecting bulbs of tulip species to assist the late Sir Daniel Hall in the preparation of a monograph of the genus but at the same time collecting important herbarium material of about 2,500 specimens.

In 1930 he became assistant to the Regius Keeper of the Royal Botanic Garden, Edinburgh, where he remained until he retired in 1954. It was here, fired with enthusiasm by the unrivalled herbarium collections of George Forrest and Kingdon Ward and the magnificent living representation of the genus *Rhododendron*, that he became an acknowledged expert publishing about seventeen papers and a book.

He later, as is well known to an increasingly wide circle of interested people, accepted charge of the gardens at Inverewe House, Wester Ross, which had been transferred to the charge of the National Trust for Scotland, and in addition became the Trusts general gardens advisor and organised its spring cruises. He was a holder of the Veitch Memorial Medal of the Royal Horticultural Society and the Victoria Medal of Honour.

D. W. YOUNG

D. W. Young, O.B.E., who died in December 1960, was one of the band of pioneers who did so much for the Forestry Commission. After service as a forestry inspector with the old Board of Agriculture and Fisheries, and a spell with the Home Grown Timber Committee of the First World War, Young joined the Forestry Commission in 1919 as Divisional Officer, North Wales. In 1925 he went to the Forest of Dean as Deputy Surveyor, and in 1931 he took up the post of Deputy Surveyor of the New Forest. After 18 years' service in the New Forest he retired in 1949.

For nearly two years after his retirement he was engaged in the preparation of the New Forest Atlas of Common Rights, which listed all the properties in the forest to which common rights are attached. He also played an important part in the compilation of the Forestry Commission Guide to the New Forest, published in 1951. To this he contributed informative articles on the Forest Woodlands, the Forester's task, the Court of Verderers, and the Commoners' Animals.

Young was a Justice of the Peace of the New Forest for many years. Apart from his forestry activities, he was a keen naturalist. He was devoted to church work and was at one time rector's warden at Minstead. Soon after his retirement he went to live at Beaulieu, where he became secretary of the Fabric Committee for the restoration of the Church. He leaves a wife and two sons. A third son died on active service during the last war.

W. MacF. ROBERTSON

W. M. Robertson died in full harness in January 1961 after nearly a decade of sterling work as Editor-Secretary of the Empire Forestry Association in which post he succeeded the late H. R. Blanford.

He read forestry at Edinburgh University under Stebbing after active service in the First World War and became later Conservator of Forests in Tanganyika.

He was intensely interested in all aspects of forestry. A true Scot, he threw himself heart and soul into the work of the Association and brought to this work a natural friendliness and sense of co-operation which was constantly shown and will long be remembered by his many friends and by all who worked with him.

J. D. D. EVANS

Major John David Douglas Evans, who died at his home, Ffrwdgrech, Brecon, in January 1961, was president of the Royal Forestry Society of England and Wales from 1952 to 1954. His woodlands won the Royal Agricultural Society's gold medal in 1959. He was High Sheriff of Breconshire in 1912 and Mayor of Brecon from 1920 to 1922. Evans was Master of the Brecon Hunt from 1922 to 1935 and had also been chairman of the Usk Board of Conservators.

He had for many years judged forestry entries at agricultural shows not only in Wales and the Midlands but as far afield as Yorkshire. He frequently threw open his woodlands at Ffrwdgrech to visitors and spared no pains to make these visits as valuable as possible. He had always something interesting to show and to explain in estate forestry management. Among other things his interesting experimental mixture of thuja and larch may be particularly mentioned.

He had long been a member of this society and his son is also a member.

CORRESPONDENCE

The Use of Barrier Layer Cells as Radiation Meters

To the Editor of *Forestry*:

Sir, Barrier cells have been used for a number of years to measure the light intensity prevailing in a variety of botanical and silvicultural investigations. Recently, the use of such cells for light measurements in woodlands has been assailed on a number of counts (Richardson, 1959). The more important of these are enumerated below:

1. 'When barrier layer cells are calibrated for use in woodlands the emission spectrum of the standard light source should conform to the spectral curve of photosynthesis.' 'The barrier layer cell used by Fairbairn (1958) was calibrated with a high pressure mercury vapour lamp as a light source (Connor, 1958).' 'Fairbairn (1958) uses a barrier layer cell with . . . maximum response at the same wavelength as that of the human eye. This may have some merit as far as the human physiologist is concerned, but in studies of plant growth it is a distinct disadvantage. . . .'

2. Flat cells 'show a preference in recording radiation incident in a direction normal to the receiving surface. Their sensitivity, in fact, varies according to the direction of the incident radiation.'

3. 'Raising the flat meter brought about considerable differences in micro-ammeter readings which were not consistent; the spherical meter, on the other hand, could be moved in any direction without affecting the measurement.'

4. 'Variations in light quality under a tree canopy are such that long term records, with barrier layer cells, have a strictly limited validity; indeed it is doubtful whether the information they provide justifies the time and effort expended in obtaining it.'

After this last comment it is perhaps surprising to discover that barrier layer cells are the active agents in the spherical meter used by Richardson and discussed by him in the latter part of his paper.

Considerable interest is being shown in the use of barrier layer cells by research workers in several countries and a number of inquiries for further information has been received by us. We would like, therefore, to comment on these statements in view of this criticism of our procedures, the more so as some at least appear to arise from a misunderstanding of the relevant papers.

We used a high-pressure mercury vapour lamp to produce a bright, very steady point source of light. This ensured that by varying the distance of the cell from the lamp a considerable range of illumination could be studied. The constancy of the light output was desirable as the calibrations would occupy a whole day or more. The importance of having a point source of light is that the inverse square law could be used to check the readings of the cell and the two meters against which the cell was being calibrated. The spectral composition of this light is quite irrelevant to our purpose which was to ensure that the output current was proportional to the illumination. For simplicity, suppose the lamp emitted light of one (arbitrary) wavelength only. The two standard meters would each give a reading appropriate to the intensity of illumination and their responses at that wavelength. The cell under examination would behave similarly. By varying the illumination a relation between current output of the cell and illumination could be obtained. All calibrations were performed with the same light source and standardized meters. Each cell was therefore calibrated for linearity of response under the same conditions, and provided the cells are identical in spectral response and are going to be used to evaluate light distributions having a common spectral composition, this procedure is quite adequate. We believe that

individual cells do not differ significantly in spectral response and we would point out that our long term experiments were conducted in stands of pure Norway spruce of different densities in which full data of thinning and other operations have been recorded for some thirty years. It is known from the work of Knuchel (1914) that the spectral composition of light within conifer stands differs only slightly, if at all, from that of full daylight. Hence both conditions are met.

It is quite true to say that serious errors can arise where light under a canopy differs in spectral composition from outside light. This is one of the questions dealt with in a paper in preparation by the present writers.

We do not agree that in general the calibration light source should have a spectral distribution similar to that of the photosynthesis absorption curve. If it is agreed that the primary growth producing effect of light on a tree is controlled by the process of photosynthesis then the spectral response of the cell should correspond to the absorption curve of photosynthesis. There are, however, so many aspects of plant development which depend in various ways on the different regions of the spectrum that we would hesitate to select any one spectral distribution. Further it is known that saturation is attained in photosynthesis at relatively low light intensities for deciduous trees while for certain species of pine the rate increases steadily with light intensity (Kramer, 1957).

The purpose of our work was specifically to measure the light reaching the surface of the forest floor in relation to the onset of natural regeneration. The floor being reasonably flat, it appeared natural to us to consider the illumination of that surface. For the subsequent development of young regeneration under a canopy and for the growth of a tree in the open we would agree that the proper parameter to measure would be the flux of light into a volume. We will discuss flat and spherical cells later. At this point we would like to consider the illumination of a surface and the behaviour of flat cells.

The illumination of a surface is defined as the light energy received per unit area per unit time. It is no defect which causes a plane photometer to give a reading proportional to the cosine of the angle of incidence. Consider a light beam of uniform circular cross-section falling vertically on a circular cell of the same diameter. All the incident light is received by the cell. Now direct the same beam obliquely on to the cell. The plane containing the cell now intersects the oblique beam not in a circle but in an ellipse whose minor axis is the diameter of the cell but whose major axis is greater. The light in the beam is now spread over a larger area and part of it misses the area of the cell completely. Elementary trigonometry shows that the light received by the cell is that received by the area of the ellipse (i.e. the total light) multiplied by the cosine of the angle of incidence. The sensitivity does not vary; rather the cell records the light which actually falls on it.

It has been known for some time that the reading given by a flat cell under a canopy changes with the height of the cell above ground (Fairbairn, 1958), but the work of Vézina (1960) has shown that for different stands of beech and of spruce the light received at a height of 1·3 metres bears an approximately constant ratio to that at ground level. Thus if cells are used at a fixed height above the forest floor, their readings should be proportional, on the average, to those that would be obtained on the ground. We would presume a non uniform pattern of light under a tree canopy and so are not surprised that the various readings are classed as inconsistent. It would be surprising if it were otherwise. There is no simple relation in general between the light at various heights under a canopy. What is perhaps surprising is that the spherical meter can, as stated by Richardson, be moved in any direction without changing the reading.

If the spherical meter is raised vertically and still reads the same, it means that the increase in the 'vertical light' is being exactly compensated by a decrease in side and bottom

light, i.e. the light flux is constant. This would be a very important result and is one that will bear further examination.

The graphs given by Richardson comparing the instantaneous readings of a flat with a spherical cell are irregular. The graph given by Atkins (1957) of instantaneous flat cell readings and fifteen-minute integrated light values on a spherical meter are remarkably consistent and his ratio of the observed light readings is very much more constant.

In contrasting the behaviour of flat and spherical cells the works of Giovanelli (1953) and Middleton (1953) are of importance. The former has shown how important is the choice of material for the spherical diffusing screen. The latter has shown that additional diffusing screens may be required in addition to the spherical screen in order to achieve uniformity of response in all directions. It is known theoretically that for perfectly diffuse light the readings obtained on a flat cell will differ only by a constant factor from those obtained by a spherical cell. Wallace (1937) in an admirable discussion of this subject, shows the perfect similarity of response of the two types of instrument when the sky is clouded over.

It would be of importance if data could be accumulated showing conclusively that the growth of a young tree under a canopy is directly related to the light readings obtained on a spherical meter as opposed to a flat horizontal cell.

We are only too aware of the great difficulties concerned with the measurement of light in the open and in the forest, of the differences of wavelengths in mixed leaf-tree and in coniferous stands, of the investigations required in connexion with germination and the ensuing physiological responses to different wavelengths, correlated with the factors of atmospheric and soil moisture, temperature and other locality factors. This note may, however, be of some assistance to those who may be working with the barrier layer cell or who are contemplating its use.

The following references are of importance:

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Middleton, W. E. K. (1953): *Ecology*, xxxiv. 416.
Richardson, S. D. (1959): *Forestry*, xxxii. 126.
Vézina, P. E. (1960): *Memoire: Institut Suisse de Recherches Forestières*, xxxvi, Fasc. 2.
Wallace, R. H. (1937): *Plant Physiology*, xii. 647.

Yours faithfully,

R. D. Connor and W. A. Fairbairn

Department of Foresty,
10 George Square,
Edinburgh, 8.

MISCELLANEOUS

Honour. In New Year Honours List, 1961. O.B.E. Mr. W. R. Day, Department of Forestry, Oxford. M.B.E. Mr. Duncan Ross, Glen Taner.

Society's meeting, 1961. The Society visits west-central Wales and will meet in the last week of September with headquarters at Aberwystwyth.

British Association, 1961. The Association will meet at Norwich from August 30 to September 6. The Chairman of the Forestry Section is Dr. L. Chalk. Mr. T. H. Owen, University College of North Wales, is Secretary. Mr. R. Chard, Forestry Commission, Brandon, is the local Secretary. For details of membership of the Association, the Secretary, British Association, 18 Adam Street, London, W.C. 2, should be addressed.

Filmstrips. We have received from Educational Productions Limited, East Ardsley, Wakefield, Yorkshire, a filmstrip in colour consisting of 33 frames mostly supplied by the Forestry Commission together with notes written by John H. Elliott. This filmstrip is the third of a series of filmstrips on trees and shows a selection of conifers of economic importance. Strips already published in this series are 'Flowering Trees' and 'Catkin Bearing Trees'. The price of 'Coniferous Trees' is 27*s.* 6*d.* Full details available from the makers.

Corrigendum. The Publishers of *The New Forest* reviewed by N. V. Brasnett on page 229 of volume xxxiii, should be J. M. Dent and Sons Ltd., Aldine House, Bedford Street, London, W.C. 1, and not the Galley Press as stated at the head of the review.

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